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FINAL REPORT

R-OU-303

VECTORBORNE DISEASE AND CONTROL

By

T. Johnson and D. R. Johnston

Contract No. N0022867C0689

TRC-67-43

RESEARCH TRIANGLE PARK, NORTH CAROLINA 27709

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OPERATIONS RESEARCH AND ECONOMICS DIVISION
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SUMMARY OF

FINAL REPORT R-OU-303

Vectorborne Disease and Control

by

T. Johnson and D. R. Johnston

for

OFFICE OF CIVIL DEFENSE
OFFICE OF THE SECRETARY OF THE ARMY
Washington, D. C. 20310

Sponsored by the Office of Civil Defense, Office of the Secretary of the Army through the Technical Management Office, U. S. Naval Radiological Defense Laboratory.

under

OCD Work Unit 3412C
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Vectorborne Disease and Control

I. SUMMARY

Recent studies have established that conditions conducive to the development and spread of many diseases will likely prevail among the surviving population of the United States during the postattack period. The "best" estimates of these previous studies of the maximum danger have indicated that the diseases would not annihilate the surviving population; however, they would threaten a large portion. In fact, vectorborne diseases were evaluated as a potentially less significant threat than enteric diseases. Because of differing evaluations of the ranking of importance within the set of vectorborne diseases and historical decimation of populations by certain vectorborne diseases, the present evaluation of the potential postattack vectorborne disease threat was initiated.

The present evaluation is limited to diseases estimated to be of potential major concern in the United States in the postattack period.[1/] The relative importance of the five selected diseases is analyzed for the first year following a nuclear attack and the data are presented on a case-per-year basis.

The approach taken in this evaluation was to reexamine quantitative estimates of previous studies, modify appropriate inputs and formulations, and compare these with historical occurrences of vectorborne diseases. Occurrences in the nineteenth and early twentieth centuries were chosen because the general level of medical knowledge more closely approximated that which exists now and would exist postattack than did earlier epidemics. Epidemics were found during that period which exemplified the lack of knowledge of the specific causes of the disease and the specific medications (antibiotics, sulfa drugs, etc.) used for treatment (the dates of discovery of causative agents are noted in Appendix A). Many of these epidemics occurred in areas of locally dense population and under refugee type conditions. In a postattack environment the shortage of medications, public health and medical personnel, and vector control supplies might approximate the nineteenth and early twentieth century historical experience.

Parameters affecting the development of vectorborne diseases were examined and estimates were made of the worktime lost by nonfatal cases as well as by potential fatalities. An important step was to evaluate the regions of the United States which

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1/ The transmission of diseases by flyborne filth was not considered. The vectorborne filth-related diseases were categorized with the enteric disease group for this analysis.

would be at risk to each of the diseases in a postattack period. The range of independent estimates of the potential risk from plague and epidemic typhus obtained in this analysis bracketed the estimates obtained in recent analyses.[2/,3/] Summing the most severe estimates of risk from vectorborne diseases (considering United States regions at risk from each disease) gave approximately 4.0 percent of the surviving population as cases and 1.35 percent as fatalities during the first year postattack. Summing the least severe estimates gave 0.34 and 0.16 percent, respectively. A "best" estimate might be given as 2 percent cases and 0.75 percent fatalities due to vectorborne diseases.

According to the present evaluation, plague is potentially the most serious postattack vectorborne disease threat; epidemic typhus, mosquitoborne encephalitis, rabies, and murine typhus follow in order of importance as listed. Rabies was included because of the formal epidemiological similarity to vectorborne diseases. Appendix A contains a brief description of each disease.

The "best" estimate indicates that vectorborne diseases are a potential postattack health problem of considerable potential (0.75 percent of 100 million survivors is 750,000 potential deaths). However, in comparison with the enteric disease threat estimated in previous studies,[4/] the vectorborne disease threat is an order of magnitude less than the postattack disease threat from enteric and man-to-man diseases.

Methods for control of rodents, rodent ectoparasites, lice, and mosquitoes are reviewed. From consideration of habits and population potential of rats, a variety of rat control strategies are suggested depending on the fallout and direct weapons-effects situation. In all cases the emphasis should be to reduce rat harborage and food availability in the vicinity of human populations with rodenticides and rodent ectoparasite control used as supplementary measures when necessary. The indicated method of control of mosquitoborne encephalitis is aerial spraying to control outbreaks as they are detected.

Normal inventories of pesticides are estimated to be sufficient in quantity and distribution to facilitate the required postattack vector control operations. Distribution is inferred from the locations of pesticide producers and formulators.

2/ J. B. Hallan, et al., Review and Evaluation of the National Emergency Health Preparedness Program, R-OU-209. Research Triangle Institute, Research Triangle Park, N. C., November 30, 1966.

3/ R. S. Titchen, Late Post Nuclear Attack Health Problems Study, presented to the 30th national meeting of Operations Research Society of America, Durham, N. C., October 1966.

4/ Ibid.

The relative importance of the vectorborne disease postattack threat indicates only low-cost preattack preparations such as recognition of the threat in plans and the maintenance of records of commercial inventories of supplies rather than extensive stockpiling. An exception may be the creation during a crisis period of small inventories of DDT in shelters to combat pediculosis before epidemic typhus has a chance to develop. Informing the public of the threats from vectorborne diseases in the postattack period and of methods for reducing the threats is probably the most important single action to be taken. If knowledgeable public health personnel are utilized, they could inform the public during the in-shelter period using the Emergency Broadcast System (EBS). The EBS is the system of non-government broadcast facilities and services which will remain operational during and following an Emergency Action Condition so as to permit communication with a substantial portion of the general public.

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Final Report

R-OU-303

Vectorborne Disease and Control

OCD Work Unit 3412C
Contract No. N0022867C0689

by

T. Johnson and D. R. Johnston

Research Triangle Institute
Operations Research and Economics Division
Research Triangle Park, North Carolina

Approved by:

for Edward L. Hill
E. A. Parsons, Director

June 1968

ABSTRACT

This study develops quantitative estimates of the potential postattack threat from vectorborne diseases. The diseases chosen for analysis on the basis of previous estimates of importance are plague, epidemic typhus, murine typhus, mosquitoborne encephalitis, and rabies. The analysis is based on a set of explicit assumptions about postattack medical services and command-and-control in the absence of specific plans to combat vectorborne diseases. The regional distribution of risk is considered. It is concluded that in the absence of specific preattack preparations, the best estimate is that 2 percent of the survivors may contract one of these diseases and 0.75 percent of the survivors may die from one of these diseases. Plague in the western states might be expected to account for one-half of the cases and two-thirds of the deaths from vectorborne diseases. Thus vectorborne diseases are a potential postattack problem, but are less of a potential hazard than the enteric or the man-to-man disease groups.

Methods of control of rodents, rodent ectoparasites, lice, and mosquitoes are reviewed. Normal inventories of pesticides are estimated to be adequate in quantity and distribution to support postattack vector control operations. Dissemination of information in the postattack period is judged to be of prime importance in controlling the vectorborne disease threat. The relative magnitude of the postattack vectorborne disease threat indicates that only low cost preattack preparations such as recognition of the threat in plans and the maintenance of records of commercial inventories are needed and are feasible.

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Vectorborne Disease and Control

I. SUMMARY

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II. THE APPROACH TO THREAT EVALUATION

Recent studies have approached the task of evaluating the relative potential importance of diseases in the postattack period.[5/,6/,7/] Diseases were categorized as either man-to-man, vector-to-man, or food- or water-to-man; each study estimated at least one disease from each category to be of major importance. A fourth category (tetanus), in which the organism spends a significant lifetime outside a living host or is present in the environment, was not included among the diseases estimated to be of major potential danger.

A. The Approach of Previous Studies

Different approaches were taken in each of these analyses. The Engineering-Science, Inc., analysis applied professional judgment based on field experience in public health engineering.[8/] The results of that analysis are summarized in Table I.

Table I

DISEASES OF CONCERN UNDER POSTATTACK CONDITIONS

Diseases of Primary Significance	Diseases of Secondary Significance*
Shigellosis	Murine typhus (G)
Infectious hepatitis	Plague (G)
Salmonellosis	Rocky Mountain spotted fever (G)
Typhoid	Dengue fever (I)
Amoebiasis	Malaria (I)
Mosquitoborne encephalitis	Yellow fever (I)
Rabies	
Leptospirosis	

* G - diseases which are endemic in the United States but which are limited in geographic scope.

I - nonendemic diseases which only occur if imported from outside the continental United States.

Source: Engineering-Science, Inc., Postattack Sanitation, Waste Disposal, Pest and Vector Control Requirements and Procedures. Arcadia, Calif.: Engineering-Science, Inc., Feb. 1965.

5/ J. B. Hallan, *et al.*, *op. cit.*

6/ R. S. Titchen, *op. cit.*

7/ Engineering-Science, Inc., Postattack Sanitation, Waste Disposal, Pest and Vector Control Requirements and Procedures. Arcadia, Calif.: Engineering-Science, Inc., Feb. 1965.

8/ J. Harmon, Engineering-Science, Inc. (personal communication).

Among the diseases of primary significance listed in Table I, mosquitoborne encephalitis is the only vectorborne disease in a narrow sense. Rabies and leptospirosis are diseases with no significant arthropod vectors.

Historically, leptospirosis (Weil's disease or Fort Bragg fever) is associated with damp environments contaminated with urine from infected animals such as rats, cattle, swine, dogs, and many species of wild animals. Recommended control measures are: environmental sanitation, use of protective clothing (rubber boots and gloves), and rodent control when feasible.[9/, 10/] Because its occurrence and control are basically problems of environmental sanitation, leptospirosis has been classified, in the present analysis, with the food- or water-to-man diseases such as typhoid, salmonellosis, etc.

Rabies is transmitted through the bite of an infected animal. Thus, it is similar in epidemiology to vectorborne diseases such as murine typhus and mosquitoborne encephalitis; that is, sporadic cases of rabies are transferred directly to man from infected animals during an epizootic (an epidemic in an animal population). The estimated potential threat of rabies is compared in this analysis with the true vectorborne diseases.

The analyses of Hallan, et al.,[11/] and Titchen[12/] evaluated diseases in the postattack period on the basis of the expected number of fatalities. This expected number was the calculated product of three essentially independent factors, as follows:

$$\begin{bmatrix}\text{Probability of}\\ \text{the source of}\\ \text{the infectious}\\ \text{organism in the}\\ \text{local environment}\end{bmatrix} \times \begin{bmatrix}\text{Expected number}\\ \text{of the group}\\ \text{contracting the}\\ \text{disease under the}\\ \text{specified conditions}\end{bmatrix} \times \begin{bmatrix}\text{Case fatality}\\ \text{ratio under}\\ \text{the specified}\\ \text{conditions}\end{bmatrix} = \begin{matrix}\text{Expected}\\ \text{number of}\\ \text{fatalities}\end{matrix} \qquad \text{(Eq. 1-1)}$$

Each of the three factors was then estimated by a medical consultant for each disease which had passed an initial screening for potential importance in the United States during the first year postattack.

The sixteen communicable diseases which were analyzed and their ranking by expected number of fatalities are given in Figure 1. This analysis was based on the assumption of "no countermeasures" in an effort to establish the maximum potential "regret" (as defined in that report) if no action were taken. The total population

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9/ F. H. Top, Communicable and Infectious Diseases. 5th ed. St. Louis: The C. V. Mosby Company, 1964, pp. 755-766.

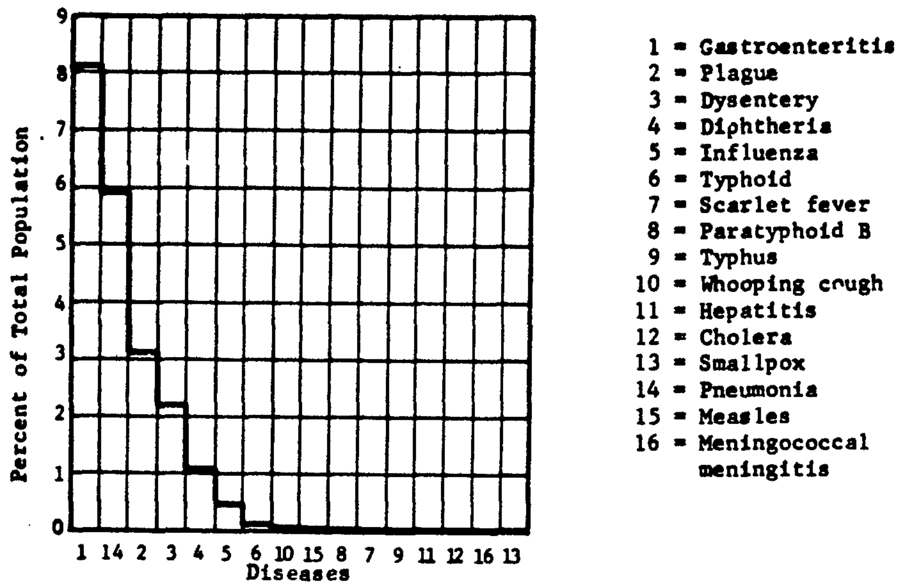
10/ P. E. Sartwell, editor, Maxcy-Rosenau, Preventive Medicine and Public Health, 9th ed. New York: Appleton-Century-Crofts, Inc., 1965, pp. 369-372.

11/ J. B. Hallan, et al., op. cit.

12/ R. S. Titchen, op. cit.

was analyzed as if it resided in "communities" of 20,000 population; no regional variation of risk was considered. Titchen makes the following statement regarding the importance distribution of diseases:

> "Note that the diseases on the 'tail' of the importance distribution are most subject to error in the sense that at least some of them should be replaced by others which were rejected on the basis of the initial screening. This group does, however, serve as a proxy for the 'residual' diseases. This kind of error, however, would seem to have no practical implications for the kinds of conclusions to be drawn."13/



Source: R. S. Titchen, Late Post Nuclear Attack Health Problems Study, presented to the 30th national meeting of Operations Research Society of America, Durham, N. C., Oct. 1966.

Fig. 1. Expected Untreated Death Rates of Major Communicable Diseases With No Countermeasures.

Plague is the only vectorborne disease of definite significance in Titchen's and Hallan's analysis. Although plague and typhus are listed among the sixteen most important diseases, typhus is in the class representing the "residual" diseases, and epidemic typhus, murine typhus, and tickborne typhus are not clearly differentiated.

13/ Titchen, op. cit.

The diseases which either have no endemic focus in the United States[14] or have been estimated to be of very minor importance in both previous studies cited[15] were eliminated, providing the following vectorborne diseases for the present analysis:

(1) Plague,

(2) Epidemic typhus,

(3) Mosquitoborne encephalitis,

(4) Murine typhus,

(5) Rabies.

In two recent studies, Mitchell[16], [17] performed an historical analysis of the importance of infectious diseases and related these occurrences in a qualitative manner to the postattack situation. Plague, epidemic typhus, and yellow fever are the vectorborne diseases considered. However, no explicit ranking of the diseases is given in these reports.

B. The Approach Taken in the Present Analysis

The approach taken in the present analysis of postattack disease threat was to compare the five vectorborne diseases listed above in greater detail than has been possible in previous studies. The steps taken were as follows:

(1) Quantification of morbidity and mortality estimates (alternative estimates of parameters were made where results were sensitive to variations in previous estimates),

(2) Comparisons with historical occurrences of vectorborne diseases,

(3) Estimates of total cases and worktime lost by nonfatal cases as well as mortality estimates.

14/ Dengue fever, malaria, and yellow fever--all mosquitoborne diseases--have a relatively difficult mode of transmission that requires a significant initial focus for "takeoff" into an epidemic.

15/ Rocky Mountain spotted fever, according to an estimation by Engineering-Science, Inc., would not be a significantly increased hazard in the postattack period. Only 262 and 249 cases of tickborne typhus were reported in 1965 and 1966, respectively. (Communicable Disease Center, Public Health Service, U. S. Department of Health, Education. and Welfare, Morbidity and Mortality. Vol. 15, No. 52, December 24, 1966). Untreated death rates run approximately 20 percent. However, even a factor-of-10 increase in the association of people with tick-infested areas during the postattack period, would not make this disease of comparable importance to those more carefully analyzed. Even by assuming current underreporting, this should not alter the conclusions.

16/ H. H. Mitchell, Plague in the United States: An Assessment of its Significance as a Problem Following a Thermonuclear War. RM-4968-TAB. Santa Monica, Calif.: The RAND Corporation, June 1966.

17/ H. H. Mitchell, Survey of the Infectious Disease Problem as It Relates to the Postattack Environment, RM-5090-TAB. Santa Monica, Calif.: The RAND Corporation, June 1966.

In addition, several assumptions and conventions were required for this analysis of the potential importance of vectorborne diseases in the postattack period.

1. Basic Assumptions

The present analysis was limited to the potential threat during the first year postattack. Seasonal effects were discounted because the refined analysis required to evaluate the seasonal effects did not seem justified. In the absence of preattack preparations, neither of the two previous types of assumptions--no countermeasures or "reasonable" countermeasures--seemed entirely desirable. As an alternative, a specific set of assumptions was made. The estimates made under these assumptions were then compared to the estimates made assuming no countermeasures. No quantitative estimates were made based on the "reasonable" countermeasures. The present analysis is based on the assumptions of postattack conditions in the absence of specific preattack plans as follows:

a) Control (law and order) - Sufficient governmental authority will remain and movements of people will be limited to broadly defined geographic areas as necessary so that recognized diseases will be confined to the area of endemicity.

b) Information (communication) - Information concerning major epidemics will be disseminated and communications for such major information will be available to support the control function.

c) Knowledge - Public knowledge of health measures and public ignorance of specific countermeasures will remain at the preattack level unless information about specific countermeasures is supplied.

d) Medical resources - Special purpose medical resources will not be available to combat vectorborne diseases. Provision of additional medical resources would reduce the risk from vectorborne disease; however, the first and most effective line of attack would be vector control.

e) Professional health personnel - Physicians will not be able to treat individual cases but will be available to advise on the treatment of patients. Public Health professionals will similarly be available to advise on disease prevention and control.

Assumptions a and b support the calculation of risk from a specific disease which is limited to the rather broad regions of the country in which the disease may be considered to be endemic. The elimination of diseases not endemic to the United States is also supported by these assumptions. Assumptions c, d, and e support the choice of illustrative epidemics in relatively recent times rather than those of the middle ages. Even under these assumptions the postattack

medical knowledge and capability might exceed those prevailing during the epidemics chosen for the calculations. The epidemics chosen are merely presented as reasonable under these assumptions.

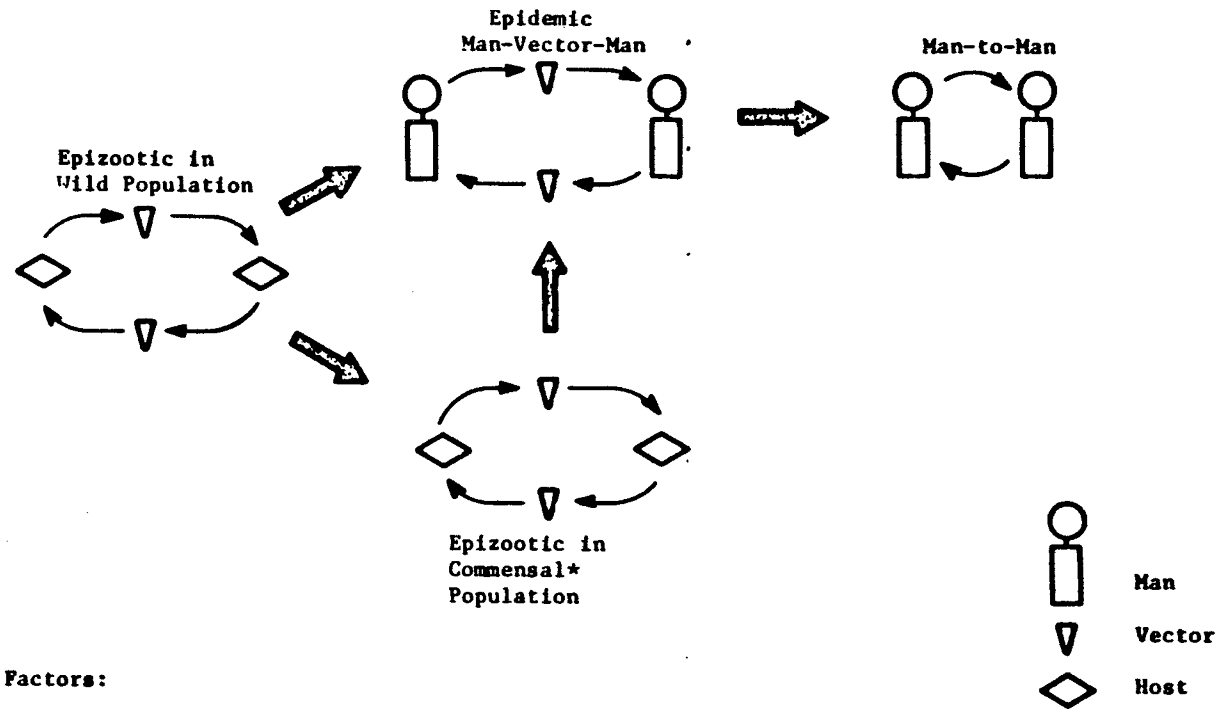
Under these assumptions, the postattack vectorborne disease situation should more closely resemble adverse conditions of more recent historical occurrence than earlier occurrences (e.g., the "Black Death" of Europe in the fourteenth century). Therefore, data for nineteenth and early twentieth century epidemics were analyzed. Also, the data from more recent occurrences appear to be more reliable than data from earlier occurrences. Much of the data on population and epidemic size which have been compared in this analysis are estimates. However, the estimates of more recent events are more adequately supported by census data and demographic analyses than earlier estimates.

2. Transmission of Vectorborne Diseases

Vectorborne diseases cover a wide range of epidemiological complexities even when limited to the five chosen diseases. The schematic reprecentation of disease cycles and transfers (see Figure 2) illustrates the possibilities for epidemics (epizootics) in distinct animal populations. For each animal population the probabilities and/or mechanisms of transfer to the human population may be different. In the human population, cycles may be man-vector-man or the disease may take a form where it is transferred man-to-man (the pneumonic form of plague).

Factors affecting the development and spread of each of the vectorborne diseases are: (a) the existence of a focus of infection, (b) the development of host populations, (c) the development of vector populations, and (d) the transfer of disease between members of the population (including the transition in form which may occur if an individual suffering from bubonic plague develops the pneumonic form.

Only endemic foci are considered since it is assumed that knowledge and control will be sufficient to prevent the importation of these diseases during the first year postattack. (Soldiers returning from Viet Nam with plague might bring this assumption into question.) The locality of the foci of infection is the main consideration in establishing regional limits to the risk from each disease.



Factors:

(a) Endemic foci
(b) Host development
(c) Vector development
(d) Transfer

* a commensal population is one which lives in close contact with man.

Fig. 2. Transmission of Vectorborne Diseases

The arthropod vector and animal host populations are shown for each of the five selected diseases in Table II.

All of the transmission schemes depicted in Figure 2 are not operative for any one disease. The specific schematic of disease development and transfer for each of the five diseases analyzed are shown in Figure 3. For example, the development of plague includes all modes of transmission except the man-vector-man. However, in the development of epidemic typhus only the man-vector-man mode is significant.

3. Factorization of Effects

The three-factor analysis of expected numbers of fatalities used by Titchen is not appropriate for diseases which occur only sporadically in the human population as transfers from an epizootic. To apply Titchen's descriptive flow-type analysis to the more complex cases would require the estimation of the following for each host population:

(1) probability of initial infection plus probability of transfer from another population.

(2) distribution of size of epidemic in each population given the presence of initial infection.

(3) transfer rate to each other population, including human, for each epidemic size.

(4) case fatality rate in each population.

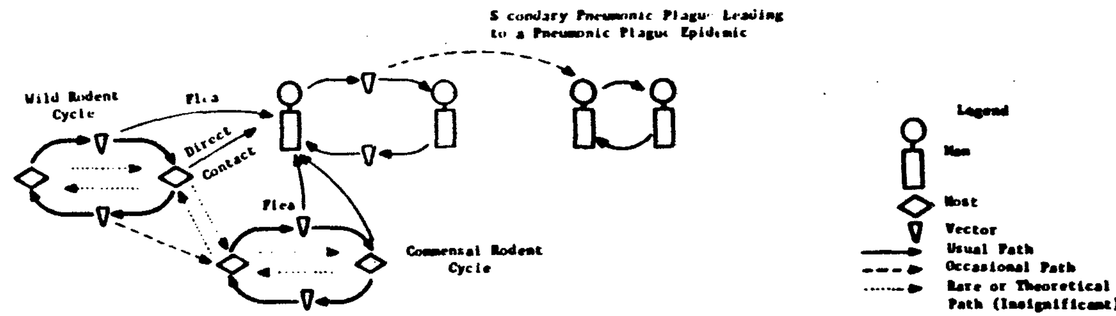
The evaluation of the number of human deaths would then involve calculations which have never been performed. The observation of the occurrence of a human case yields some information and thus affects the conditional probabilities of a number of infectives in the host population, but no solution based on this Bayesian type analysis has been found. Mosquitoborne encephalitis, murine typhus, and rabies are in this category since no significant man-to-man or man-vector-man transmission occurs in these diseases.

Thus an alternative three-factor analysis was devised to analyze mosquito-borne encephalitis, murine typhus, and rabies. The three essentially independent factors considered are: (1) incidence of the disease (case rate) under the assumed adverse conditions, (2) postattack frequency of these conditions, and (3) case fatality rate under these conditions. Since potential "regret" estimates were desired, the factors were formulated as follows:

Table II

VECTOR-HOST SETS OF CONCERN

Diseases	Hosts	Vectors	Comments
Plague	Wild and commensal rodents	Fleas (also may be reservoirs)	Transfer to man may occur by direct contact with infected rodent. Bubonic plague may develop into the pneumonic form and be transmitted man-to-man.
Epidemic typhus	Man	Human body lice	A case of Brill-Zinsser disease may be the initial focus in a group afflicted with pediculosis.
Mosquitoborne encephalitis	Birds and animals	Mosquitos	Types considered are: eastern and western equine and St. Louis encephalitis. Host development may include the in-migration of infected birds.
Murine typhus	Commensal rodents	Fleas	
Rabies	Wild carnivores, dogs, cats, bats, skunks, etc.	None	



Source: Kartman, L., M. F. Goldenberg, and W. T. Hubbert, "Recent Observations on the Epidemiology of Plague in the United States," American Journal of Public Health, Vol. 56, No. 9, September 1966, pp. 1554-1569.

Fig. 3a. Transmission of Plague.

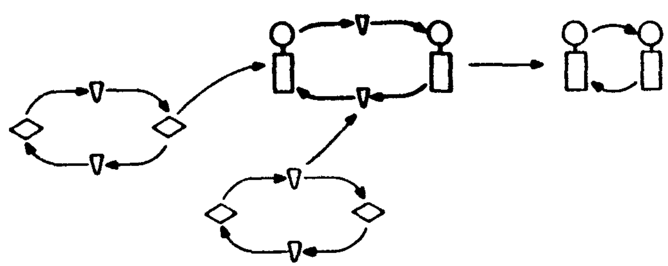


Fig. 3b. Transmission of Epidemic Typhus.

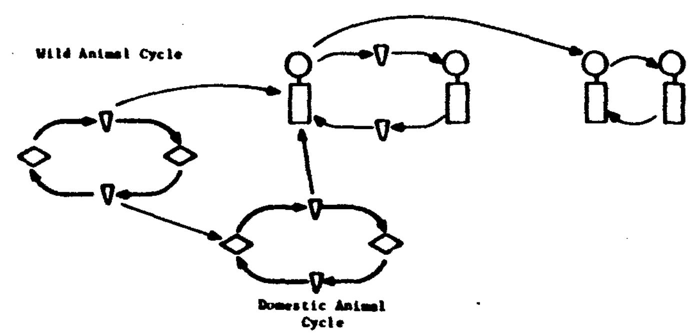


Fig. 3c. Transmission of Mosquitoborne Encephalitis

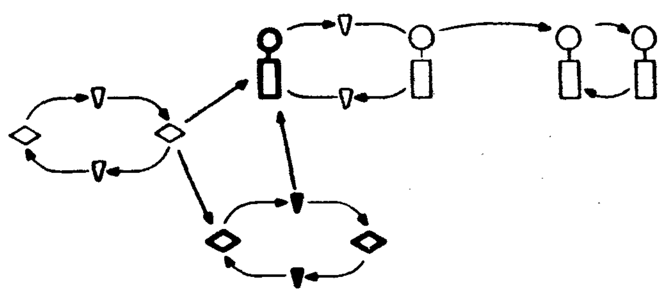


Fig. 3d. Transmission of Murine Typhus.

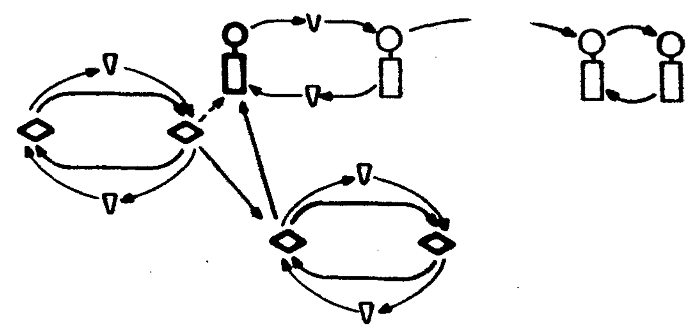


Fig. 3e. Transmission of Rabies.

$$\begin{bmatrix}\text{Estimated maximum}\\ \text{incidence of}\\ \text{cases under}\\ \text{adverse}\\ \text{conditions}\end{bmatrix} \times \begin{bmatrix}\text{Postattack}\\ \text{frequency}\\ \text{of adverse}\\ \text{conditions}\end{bmatrix} \times \begin{bmatrix}\text{Case}\\ \text{fatality}\\ \text{rate under}\\ \text{the assumed}\\ \text{conditions}\end{bmatrix} = \begin{matrix}\text{Expected}\\ \text{number of}\\ \text{fatalities}\end{matrix} \qquad \text{(Eq. 2-1)}$$

(Contrast with Titchen's factorization which is shown on page 5).

Conditions were characterized as either adverse or not conducive to the development of the disease. Under conditions not conducive to the development of the disease, it was assumed that no cases would occur.

The alternative factorization is also appropriate for analysis of man-to-man and man-vector-man diseases (pneumonic plague and epidemic typhus as well as diseases not associated with vectors). However, this factorization is offered as a supplement to, rather than a replacement for, Titchen's factorization.

Thus Titchen's approach seems more appropriate for obtaining estimates of model parameters for diseases in which a true man-to-man (or man-vector-man) epidemic occurs; in which case his three parameters describe the process. The present approach seems more appropriate for analyzing diseases which occur sporadically in humans as transfers from an epizootic source and for applying historical-occurrence data to risk analysis.

III. THE DEVELOPMENT OF THREATS

Evaluation of potential postattack threats from the vectorborne diseases chosen for analysis includes the three following steps: establishing the parameters which affect the development of the diseases into major threats; outlining the regions "at risk" within the United States which might, in a postattack period, develop conditions that favor a vectorborne disease epidemic; and finally, comparing the parametric models used in previous analyses and historical data on two bases. First, the data are compared on the basis of a uniform nationwide risk equal to the estimated risk. Next, the comparison is made on the basis of the estimated regional risk applying only to the region of major risk and zero risk applying to the rest of the nation. This section discusses the major parameters which affect the development of the diseases into major threats.

Figure 3 illustrates that, except for epidemic louseborne typhus, the occurrence of the five selected diseases in man stems from an epizootic among at least one population of lower animals. The occurrence of a host-vector-host epizootic may be represented in a rather rudimentary manner by the deterministic model for vectorborne epidemics.[18/]

In the deterministic model of host-vector-host disease spread, Bailey established that the condition for a true epidemic to occur is approximately

$$nn' > pp' \qquad \text{(Eq. 3-1)}$$

where n = total host population,

n' = total vector population,

p = relative removal rates for the host population

p' = relative removal rates for vector population.

The relative removal rate p is defined as

$$p = \gamma/\beta$$

where γ = the removal rate
(removal of infectives from the population per unit time per infection)

β = the infection rate
(infection of susceptibles per unit time per host per vector).

No experimental estimates of the parameters γ and β for the diseases being considered in this analysis have been found (such as those available for malaria). Thus, the model and these parameters (γ and β) will be used mainly to guide a heuristic discussion of the relevant parameters.

18/ N. T. J. Bailey, The Mathematical Theory of Epidemics. New York: Hafner Publishing Company, 1957, p. 29.

"It appears to be neither necessary nor possible to make detailed technical estimates of the biological consequences of nuclear war. What does seem possible and worthwhile is to collect and review biological laws, principles, and empirical generalizations systematically derived from data to see how such information can be applied to the postattack biosphere, not only to solve but to discover problems associated with given hypothetical patterns of management and control." 19/

The development of an epidemic (or epizootic) requires either an infected host or an infected vector as a source of infection in the "community." In a disease requiring an intermediate vector, development of an epidemic also requires the presence of the vector in the "community" as well as a source of infection. The mobility of hosts and vectors determine the geographical limits of the "community." Also, as implied by the definition of the relative removal rate ρ, the development of an epidemic depends on the duration of the disease in both the host and vector populations as given by γ (the rate at which infectives are removed by death or recovery). The average time required to transfer the disease from an infective in one population to a susceptible in another population is given by $1/\beta$ (the inverse of the infection rate).

This classification of the relevant features of vector populations is analogous to the classification used for the investigation of malaria.[20/] The three main vector characteristics are biting habits, infective lifetime, and infectivity. Although these parameters have not been measured precisely for the diseases considered in this analysis, the qualitative data are useful for obtaining rough estimates of risk.

The biting habits of vectors include host specificity, rate of transfer between hosts, and the feeding frequency of the vector. The host specificity and the rate of transfer between hosts are important in the spread of a vectorborne disease from an epizootic to man. The rate of transfer of vectors between hosts depends on the number of vectors per host as well as the density and distribution of the host population. The travel range of vectors is important for planning control measures such as quarantines; Table III gives general estimates of ranges for important hosts and vectors.

19/ H. Hollister, "The Ecology of the Postattack Environment," Radiation Effects on Natural Populations, A colloquium held in Philadelphia, May 23, 1965, G. A. Sarber, editor, Division of Biology and Medical Research, Argonne National Laboratory, January 1966, p. 53.

20/ G. McDonald, The Epidemiology and Control of Malaria. London: Oxford University Press, 1957.

Table III

APPROXIMATE TRAVEL RANGE OF HOSTS AND VECTORS

Vectorborne Diseases	Hosts	Host Travel Ranges*	Vectors	Vector Travel Ranges*
Plague	R. rattus (roof rat) R. norvegicus (Norway rat)	Usually a city block; (a few miles if released in unfamiliar territory, but with low survival)	Rat flea esp. Xenopsylla cheopis	Short; inches to feet on own. May travel farther on host or in grain
	Wild rodents	Usually short; a few miles for a few species	Several flea species	Short; inches to feet
Epidemic typhus	Man	Long; many miles even without modern transportation	Louse humanus corporis	Very short; transfer between hosts usually requires close contact
Murine typhus	R. rattus R. norvegicus	Usually within a city block; a few miles if released in unfamiliar territory	Rat flea esp. Xenopsylla cheopis	Short; inches to feet on own. May travel farther on host or in grain
Mosquitoborne encephalitis	Domestic fowl	Usually caged (but in close proximity to man)	Several mosquito species	Moderate; up to several miles
	Wild birds	Extremely long; hundreds of miles during migration		
	Mammals and reptiles	Short to moderate; a few miles at most		
Rabies	Wild and domestic mammals	Moderate; several miles for canine and feline species	———	———

* Range means the distance traveled by an individual host or vector in a population.

The infective lifetime of vectors, one of the factors in the relative removal rate for the vector population, is important to the carry-over of some diseases from one season to the next or from one epidemic to the next (e.g., survival of infected fleas on sylvatic rodent populations may be one method of carrying plague through the winter[21/]). Thus, the life cycle of the vector is important for planning control measures since a 100 percent kill is generally not achieved or required.

The infectivity of vectors depends on the efficiency of the vectors, susceptibility of the hosts, and the virulence of the strain of the infectious organisms transferred by the vector. Efficiency depends on the method by which a vector transfers organisms. For example, if a flea becomes "blocked" by many plague bacilli and regurgitates an injection into a host, the vector is more efficient than one which only injects a few bacilli with contaminated mouth parts. A flea is said to be "blocked" when the plague bacilli become so numerous that the gut is at least partially obstructed.

Host susceptibility depends on the average susceptibility of the species to the specific organism, the level of acquired immunity, and other factors affecting the level of resistance of individual host to infection. The susceptibility of man plays an important role in the transfer of a vectorborne disease to man from an epizootic as well as the transfer from an epidemic (man-vector-man or man-to-man).

A. Plague

The animal hosts of plague are the commensal rats (Rattus rattus, or black rat, and Rattus norvegicus, or brown rat) as well as many species of wild rodents (see Appendix B for a listing of wild hosts). The most important vectors for all species of hosts are various species of fleas.

If urban populations of the Western states were evacuated to previously unsettled country, the endemically infected species of wild rodents would be the host populations of concern (unless large numbers of commensal rodents were taken with the people). In this case host and vector populations and endemic plague might exist in the newly occupied area. If the area were initially locally plague-free, development might be similar to that described for the no-evacuation case. In the past few years, human plague in the United States has been almost exclusively traced to contact with such wild rodents. See Table IV for a summary of recent cases of

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21/ L. Kartman, et al., "Recent Observations on the Epidemiology of Plague in the United States," American Journal of Public Health, Vol. 56, No. 9 (September 1966), pp. 1554-1569. A list of the sylvatic (wild) rodents which have been found naturally plague-infected in the United States is given in Appendix B.

Table IV

CASES OF HUMAN PLAGUE REPORTED IN THE UNITED STATES, 1956-1965

Case	Age	Sex	Onset	Location	Probable Source	Original Diagnosis	Outcome
1	40+	M	June '56	Ventura Co., Calif.	Wild rodent flea	Plague	Fatal
2	4	F	Sept.'57	Boulder Co., Colo.*	Wild rodent flea	Meningitis	Fatal
3	27	M	June '59	Park Co., Colo.	Prairie dog	Tularemia	Recovered
4	11	M	June '59	Yosemite Nat'l Pk., Calif.	Wild rodent flea	Plague	Recovered
5	12	F	July '59	Bernalillo Co., N. M.	Cottontail rabbit	Plague	Fatal
6	40	M	July '59	Tuolumne Co., Calif.	Ground squirrel	Plague	Recovered
7	24	M	Feb. '60	Chaves Co., N. M.	Cottontail rabbit	Plague	Recovered
8	23	M	Feb. '60	Chaves Co., N. M.	Cottontail rabbit	Plague	Recovered
9	38	M	June '61	San Miguel Co., N. M.	Uncertain	Plague	Fatal‡
10	38	M	July '61	Santa Fe Co., N. M.+	Uncertain	Tularemia or RMSF**	Fatal
11	23	M	Aug. '61	San Miguel Co., N. M.	Uncertain	Plague	Recovered
12	28	M	Dec. '63	Apache Co., Ariz.	Rabbit	Plague	Fatal
13	3	F	June '65	McKinley Co., N. M.	Prairie dog	Meningitis	Recovered
14	2	M	July '65	McKinley Co., N. M.	Prairie dog	Meningitis	Recovered
15	9	M	Aug. '65	McKinley Co., N. M.	Prairie dog	Plague	Recovered
16	4	F	Aug. '65	McKinley Co., N. M.	Prairie dog	Mumps?	Recovered
17	3	F	Aug. '65	McKinley Co., N. M.	Prairie dog	Plague	Recovered
18	3	M	Aug. '65	McKinley Co., N. M.	Prairie dog	Plague	Recovered
19	14	M	Aug. '65	McKinley Co., N. M.	Prairie dog	Plague	Fatal‡
20	5	M	Sept.'65	Shasta Co., Calif.	Ground squirrel	Plague	Recovered

* Died in Wichita Falls, Texas

\+ Died in Boston, Mass.

‡ Secondary pneumonic involvement.

** Rocky Mountain Spotted Fever.

SOURCE: L. Kartman, M. F. Goldenburg, and W. T. Hubbert, "Recent Observations on the Epidemiology of Plague in the United States," American Journal of Public Health, Vol. 56, No. 9, (September 1966), p. 1557.

plague in the United States. If such large-scale evacuations do occur (either preattack or postattack), the educa on of the people to the danger of plague would be of highest priority.[22] Local cont.ol of wild rodent and rodent flea populations in the newly populated regions would also be indicated.

1. Rat Populations

In most urban areas there is some effort to control rat populations. In the Western part of the country, in which plague is endemic, there often are also efforts to prevent association between commensal rats and the wild rodents which may be infected by plague. In a postattack period, relaxation of controls might result in interchange of vector fleas between commensal rats and infected wild rodents and increases in rat and flea populations and consequent danger from plague to the human population. The potentiality for development of a local plague threat depends upon the proximity of endemic plague, the extent of rodent movements, and the rate of increase of rodent and flea populations as well as upon the location and the living and working habits of the human population.

The extent of endemic plague in the United States is discussed in section IV.A where the limits of risk are postulated. From the data presented in that section, it appears that population centers in the Western U. S. (New Mexico and Colorado west) should plan for the eventuality of plague based on its endemicity in nearby wild rodent populations.

Today, commensal rodent populations are held in check through a combination of limitation of the capacity of the environment to support rat populations and of predation. Davis notes that.

> " Competition, like predation is density dependent in its effects. These two factors are true controlling factors because, in a given environment, as the population increases, the proportional effect increases, thereby causing a greater control on the population."[23]

Capacity is limited through reduction of harborage and protection of potential food supplies. Predation is construed to include trapping and poisoning as well as predation by cats and dogs. The principal form of predation is poisoning.

In a postattack period harborage might be increased as the result of direct effects damage (e.g., rubble, abandoned buildings, and increased access to occupied buildings). The available food supply might be increased by damage to previously rat proof storage facilities. Combined with reduction

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22/ L. Kartman and F. Prince, personal communication.

23/ D. E. Davis, "The Characteristics of Global Rat Populations," American Journal of Public Health, Vol. 41 (1951), p. 158.

of active control efforts (poisoning and trapping), these factors might greatly increase the environmental capacity for rats. Postattack rat populations might thus be modeled by populations decimated at the initiation of the period.[24/]

A classic study of the recovery of decimated populations of brown rats[25/] showed that populations reduced to between 5 and 50 percent of the equilibrium value recovered according to the logistic equation

$$y = \frac{100}{1 + e^{-kt}}$$

where

y = population in percent of equilibrium population,

t = time measured from the point at which y reaches the mid-point of its growth,

k = rate constant in reciprocal time units.

The values of k observed in that study were between 0.1 and 0.3 per month with the large values (more rapid multiplication) corresponding to the more heavily reduced populations.

In the case reported in that study[26/] where nearly all rats were removed from a block, the rat population did not start to increase until the third year (approximately 30 months) after decimation. The long delay may be explained by the the fact that that study, as well as several more recent studies,[27/] indicate that rats seldom cross a street.

One of the studies[28/] introduced alien rats into a stable population in a city block. The aliens experienced a rate of mortality three times that of the adult residents. Although the study was not specifically designed to study emigration, the fact that several rats were found killed in the street (an otherwise rare occurrence) indicated some tendency for emigration. However, it was noted that "if they did emigrate, they did not stop in nearby blocks in appreciable numbers."

24/ The United States Strategic Bombing Survey, The Effects of Bombing on Health and Medical Services in Japan, Medical Division, 1967, states "incendiary bombing was quite effective in reducing the rat populations of cities, as no rats were observed in the burned-out areas. It is probable, even in the absence of substantiating data, that the percentage reduction in rat population was approximately that of the city destroyed."

25/ J. T. Emlen, Jr., A. W. Stokes, and C. P. Winsor, "The Rate of Recovery of Decimated Populations of Brown Rats in Nature," Ecology, Vol. 29, No. 2 (April 1948), pp. 133-145.

26/ Ibid.

27 Ibid.; see also J. D. Calhoun, "Mortality and Movement of Brown Rats in Artificially Supersaturated Populations," Journal of Wildlife Management, Vol. 12, No. 2 (1948), pp. 167-176; and D. E. Davis, J. T. Emlen, and A. W. Stokes, "Studies on Home Range of the Brown Rat," Journal of Mammology, Vol. 29, No. 3 (August 1948), pp. 209-225.

28/ Calhoun, op. cit.

An early study[29/] found that rats deposited in a strange environment did emigrate over considerable distances. It seems likely that in some cases the postattack environment might be strange enough to the resident rats (even though the geographical location is unchanged) to cause them to emigrate. Fire and flooding might particularly cause some rats to emigrate. Calhoun's results[30/] would suggest that if emigration did occur, the effect would be to introduce only a few new rats into any one block. If the preattack population were zero, this would eliminate any waiting period for population buildup to start.

Although no specifically applicable studies were found, one might postulate that certain geographical features might provide concentrated emigration routes for rats on the move.[31/] If concentrated emigration routes were to develop, initially heavy populations of rats might emigrate into an area--possibly even to the extent that the equilibrium population would be temporarily exceeded. If this were to occur, the high mortality found by Calhoun plus continuation of emigration seem likely to quickly reduce the population to the equilibrium value or below.

It seems logical to expect that rats already "on the move" would not permanently stop in a capacitated environment. This, coupled with the observed high mortality rate of immigrants, makes it appear to be a less likely possibility that the initially excessive immigrant population would decline toward equilibrium at the rate observed for initially resident populations when the capacity of the environment is reduced. This type of reduction of a resident population (due only to a change in environmental capacity) is shown in Figure 4.

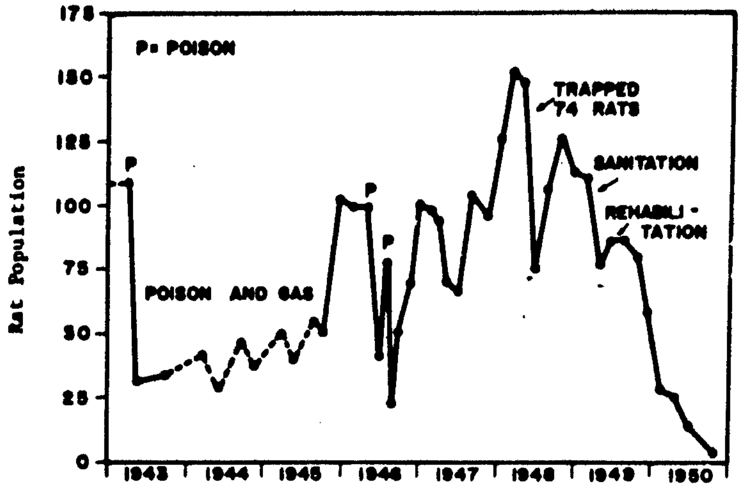
The possibilities for the change in postattack rat populations are summarized in Figure 5.[32/]

29/ R. H. Creel, "The Migratory Habits of Rats with Special Reference to the Spread of Plague," Public Health Reports, Vol. 30, No. 23 (1915), pp. 1679-1685.

30/ Calhoun, *op. cit.*

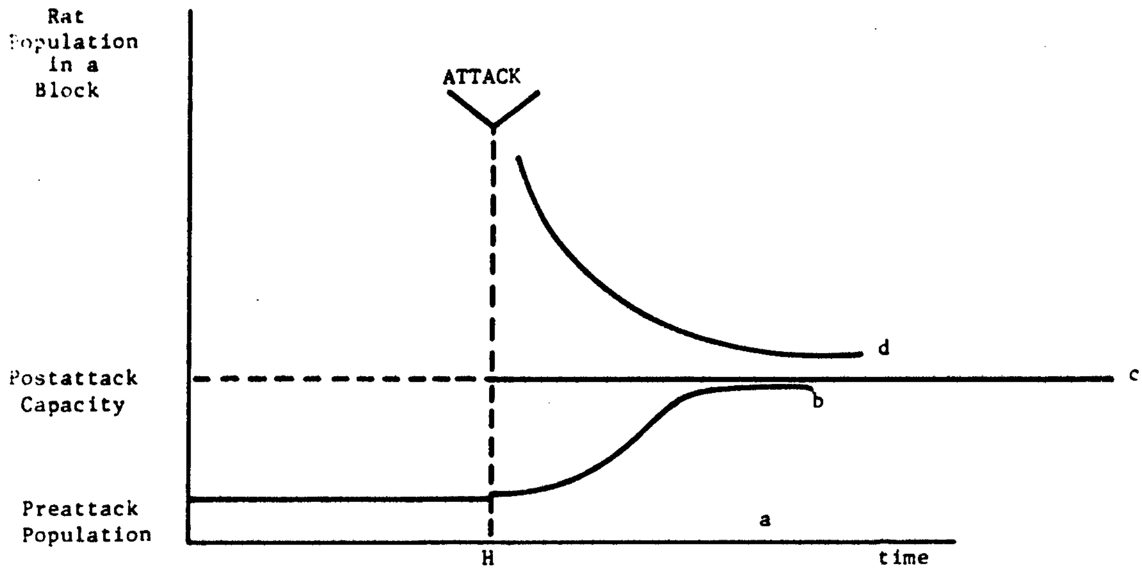
31/ As rats tend to run along fences or walls rather than in the open, they might seek protected emigration routes such as hedge rows or stream banks.

32/ For a discussion of the shapes of these curves, see Davis, "The Characteristics . . .," *op. cit.*



Source: P. E. Sartwell (ed.), Maxcy-Rosenau, Preventive Medicine and Public Health (9th ed.). New York: Appleton-Century-Crofts, Inc., 1956.

Fig. 4. History of Rat Population in Baltimore, 1943-1950.



a: no preattack or early postattack population - optimistic

b: no immigration or immigration of only small numbers to act as breeding stock - probably the most significant case

c: immigration of capacity or more with very rapid reduction to capacity population - seems unlikely unless preattack population is near postattack capacity

d: immigration population decaying to equilibrium as a resident population - the least likely case

Fig. 5. Postattack Dynamics of Rat Populations.

Radiation from fallout would also be expected to affect the rat population. Extensive work has been done to determine the lethal effects of external gamma radiation on individual rodents.[33/] However, relatively little is known about genetic or population effects of fallout contamination, i.e., effects on a free-ranging, native population in an initially intense field of radioactive surface contamination which decays approximately as $t^{-1.2}$ (t = time). Several researchers[34/] have been laying groundwork for this type of experimentation on rodent populations but no final results have been found during the present study. Study of free-ranging rats fortuitously subjected to fallout radiation[35/] has indicated that rat populations can survive bomb test fallout.

Some basic experiments in radiation biology using laboratory mice[36/] have shown effects on litter survival at doses of a few roentgens to the mother although effects were dependent upon the stage of pregnancy at irradiation. That study also found that on the day of birth, 300 roentgens did not cause any significant decrease in the later production of litters. However, during the second week a radio-sensitive stage seemed to prevail in newborn mice; 85 roentgens of exposure delivered at a continuous rate over approximately seven days caused sterility after one or two litters of reduced size.

One must also recognize the probability of ingestion of radio-nuclides and body contamination of free-ranging rats in a fallout environment. It thus seems likely that fallout will reduce rat populations to a much greater extent than through lethal external doses of gamma radiation. This indicates that ignoring radiation effects on rat populations may result in a significant overestimate of the postattack rat problem in areas with moderate to heavy fallout. However, extrapolation from laboratory to native species and from caged individuals to free-ranging populations does not seem appropriate. Definitive

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33/ A report of some very applicable recent work is given by P. B. Dunaway, L. L. Lewis, J. D. Story, J. A. Payne, and J. M. Inglis, "Radiation Effects in the Soricidae, Cricetidae, and Muridae," to appear in Second National Symposium on Radioecology Proceedings.

34/ See Radiation Effects on Natural Populations, A colloquium held in Philadelphia, May 23, 1965, G. A. Sacher, editor, Argonne National Laboratory, Argonne, Illinois, January 1966.

35/ W. B. Jackson, "The Engebi Rats - Another Chapter," Second National Symposium on Radioecology Proceedings, to be published.

36/ A. Forrslurg, "Effects of Small Doses of Ionizing Radiations," Advances in Radiation Biology, L. G. Aligestein and R. Mason, editors, Academic Press, New York, 1964.

estimates of radiation effects on the growth potential of postattack rat populations must thus await the results of the experiments mentioned above.

2. Rat Fleas

All species of fleas are not equally efficient as vectors of plague. Although wild rodent fleas are important reservoirs of plague and vectors for present day cases of plague, the following discussion is concentrated on rat fleas since it is judged that this would be the most important potential source of plague in the postattack period. Burroughs[37/] summarizes the technique of Wheeler and Douglas[38/] for computing vector efficiency as follows:

> "Three potentials of a species are considered: the infection potential, the vector potential and the transmission potential. The infection potential is based on the percentage of fleas which can be proved to be infected through demonstration of the presence of organisms in the faeces. The vector potential is determined by the percentage of fleas which may transmit plague to animals. The transmission potential is the average number of transmissions accomplished by the infective fleas when fed once daily on individual white mice. The product of these three factors represents the number of transmissions effected by a given number of fleas and is designated as the vector efficiency of the species. Stated more simply, the vector efficiency is the ratio of daily transmission to total number of fleas used in the experiment."

The results of Burroughs experiments are summarized in Table V. An additional factor which must be considered in determining the importance of a flea as a vector of plague to man is its propensity to bite man. Unfortunately, the oriental rat flea (*Xenopsylla cheopis*) is among those fleas which commonly infest the commensal rodents and which quite readily attack man if starved. Results of Webster and Chitre, and Webster quoted by Pollitzer[39/] show that *X. cheopis* females can live up to 162 days when fed on human blood (males up to 63 days) and that the *X. cheopis* females when offered daily feedings of human blood accepted 32 percent of the offers versus 53 percent for those offered guinea-pig blood and 51 percent for those offered rat blood. (*X. cheopis* males accepted 46, 75, and 67 percent of the offerings of human, guinea-pig, and rat blood respectively.)

37/ A. L. Burroughs, "Sylvatic Plague Studies, the Vector Efficiency of Nine Species of Fleas Compared with *Xenopsylla Cheopis*", *Journal of Hygiene*, Vol. 45 (1947), pp. 371-396.

38/ C. M. Wheeler and J. R. Douglas, "Transmission Studies of Sylvatic Plague," *Proceedings of the Society for Experimental Biology and Medicine*, Vol. 47 (1941), pp. 65-66.

39/ R. Pollitzer, *Plague*, World Health Organization, Geneva, 1954, pp. 324-325.

Table V

FEEDING AND TRANSMISSION DATA OF FLEAS STUDIED

	X. cheopis	N. fasciatus	O. sexdentatus sexdentatus	O. nesiotus	M. abantis	D. montanus	M. telchinum	P. irritans	O. idahoensis	E. gallinacea
No. studied	53	47	53	46	75*	66	115	57	61	48
No. feedings	718	596	466	344	743	520	898	421	451	48
No. refusals	357	120	79	161	132	224	95	188	336	0
No. blocked	31	11	15	10	9	2	0	1	0	11**
Total daily blocks	63	24	53	24	22	2	0	1	0	12
Percentage blocked	58	23	28	22	12	3	---	1.75	0	0.23**
No. transmissions by completely blocked fleas	28	7	9	3	3	0	0	0	0	12**
No. transmissions by fleas not completely blocked	7	3	0	0	1	1	5	0	0	0**
Total transmissions	35	10	9	3	4	1	5	0	0	12
No. infected at death	38	20	37	25	30*	17	31	18	4	***
Percentage infected at death	72	42	70	54	40*	25.7	17	31	7	***
No. that transmitted	20	6	5	2	2	1	5	0	0	11
Ratio transmissions to fleas used	0.660	0.213	0.17C	0.065	0.053	0.015	0.043	0	0	0.250

* Only 61 inoculated at death.
** As these fleas could not be examined *microscopically* after each meal as were the others, this data cannot be presented with certainty.
*** Not inoculated at death.

Source: A. L. Burroughs, "Sylvatic Plague Studies, the Vector Efficiency of Nine Species of Fleas Compared with Xenopsylla Cheopis," Journal of Hygiene, Vol. 45, (1947), pp. 371-396.

Seasonal variations in rat flea indexes have been studied by species and correlations with incidence of plague have been attempted. However, after summarizing the findings Pollitzer concludes:

> "Convenient though it would be, it is not possible to base forecasts of plague epidemics upon observations of seasonal changes in the incidence of the vector fleas. It is true that. . .in regions where X. cheopis is the sole important vector, plague does not assume epidemic proportions as long as the cheopis index remains below one, and that in localities where the index is constantly above this critical level, seasonal changes in the frequency of X. cheopis are often observable, which may be of value in assessing the plague situation. It had to be stated, however, that periods during which plague epidemics occur need not necessarily coincide with those during which the cheopis incidence is highest and that indeed it is a high incidence of actually infective fleas and not the frequency of potentially dangerous vector species which is of paramount importance in the spread of flea-borne plague."[40/]

3. Seasonal Prevalence

Meyer[41/] summarizes the seasonal variation in the incidence of plague as follows:

> "Epidemics of bubonic plague in man are preceded by or associated with epizootics in rats or other rodents. The great animal mortality so created favors the migration of fleas to man. This infection chain is heterogenous: the animal host, usually a rodent, and the insect vector, the flea.
>
> "The seasonal prevalence of the bubonic type depends largely on the influence of the weather on the breeding of rats and rat fleas. The Indian Commission found that in temperate regions, outbreaks occurred chiefly during the summer months. In hot, dry climates, on the other hand, it flourished during the winter, dying out in summer. Rats breed throughout the year in temperate climates, but breeding is retarded in extremes of heat or cold. With the influx of young susceptible rats, epidemics may flare up again. Similarly, breeding of rat fleas is retarded in the very cold or very hot months. Heat not only interferes with the deposition of eggs, but also prevents the eggs from developing into larvae. A temperature of 85° F. causes the plague bacillus to disappear from the stomach of the infected flea rather rapidly. A temperature of 70° F. is optimum for the propagation of an epidemic. Other factors in the epidemiology of plague in India, already mentioned, have been described by Sharif (1950).

40/ Pollitzer, op. cit., p. 503.

41/ K. F. Meyer, "Immunity in Plague: A Critical Consideration of Some Recent Studies," Journal of Immunology, (1950), pp. 139-163.

"Broods (1871) of the Indian Commission summarized his findings as follows:

"1) Plague does not maintain itself in epidemic form when the temperature exceeds 80°F. and the saturation deficiency exceeds 0.30 inch.

"2) Plague epidemics are rapidly brought to an end when the saturation deficiency is high, even when the mean temperature throughout and after the termination of the epidemic has been considerably below 80°F.

"3) Plague epidemics may begin to be intensified when the mean temperature rises well above 80°F., provided the saturation deficiency is below 0.30 inch.

"4) In some districts in India and in certain tropical islands (e.g., Java and Mauritius) where climatic conditions favor the incidence and spread of plague throughout the year, outbreaks may be spaced indifferently at all seasons.

"In North America, murine plague connected with the Oriental flea has remained restricted to a narrow Pacific Coast area and the Gulf and southern Atlantic Coast area with smaller and spotty extensions in the southern river valleys. Where the cheopis flea populations reach high numbers and also affect a high percentage of domestic rats, murine plague may appear. In the northern, relatively cold cities, the annual mean of the flea population is too low to favor rat plague. The northern rat flea (Nosopsylla fasciatus) together with the fleas from wild mice may have played a role in the murine epizootic of plague in Tacoma in 1942 (Mohr, 1951).

"Meteorologic conditions also greatly influence the form plague will take in man. The severe epidemics of primary pneumonia have occurred during periods of constantly low temperature and high relative humidity. . . ."

B. Epidemic Typhus

The development of an epidemic of epidemic (louseborne) typhus requires an initial source of infection, the presence of the human body louse as the vector, and close association of people for the lice to transfer. Because of the temperature requirements of the louse and the harborage provided to the louse by heavy clothing, typhus has been especially prominent in the winter-to-spring season of the year. Thus, a typhus epidemic during the first year postattack would be more likely if the attack occurred in the late fall or early winter with a season favorable to the development of lice immediately following the attack.

The life cycle of the louse takes approximately 16 days when the egg, larva, and nymphs remain on the body. The female then lays a few eggs a day (one to a dozen) up to a total of 275 to 300.[42] Thus, although lice might be spread throughout the human population of a shelter from a few initially infested individuals, a period

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42/ Maxcy, K. F., ed., Rosenau, Preventive Medicine and Public Health. New York: Appleton-Century-Crofts, Inc., 1956.

considerably longer than the standard two-week shelter stay time would be required for an explosion of the louse population to levels threatening the spread of epidemic typhus if only a small fraction of the human population were initially infested. The extent of louse infestation required to support a typhus epidemic is illustrated by experiences in World War II.43/

The time required for the buildup of the louse population, plus the 6- to 15-day incubation period of the disease in humans indicates that a typhus epidemic would not be detected during a two-week shelter stay time. However, lice could become widespread among the population from a few initially infected individuals. A few individuals might also be infected from a single case of Brill-Zinsser disease even with only a few lice present.

Conditions could thus be established for the development of epidemic typhus in the post shelter period when people might still live under crowded, primitive conditions. The potential rate of buildup of a typhus epidemic is illustrated by the Japanese data in Figure 6.

C. Murine Typhus, Mosquitoborne Encephalitis, and Rabies

The development of a threat from murine typhus follows much the same course as the threat from plague except that the commensal rodents appear to be the only important foci of infection and no man-to-man transmission mode exists. The development of a murine typhus threat requires a focus of infection, a population of murine rodents, and vector fleas. In a region of endemicity the development of a murine typhus threat depends upon the development and association with man of a rat population infested with vector fleas. The oriental rat flea, *X. cheopis*, is also the most important vector for murine typhus although other fleas may also transmit the rickettsiae.44/ Thus as with plague, the main concern is with the development of an infected rat population infested with vector fleas.

The complete epidemiological description of mosquitoborne encephalitis is very complex. Several different host populations may be involved at any one time. The *Culex* mosquitoes which are the main vectors of encephalitis breed prolifically,

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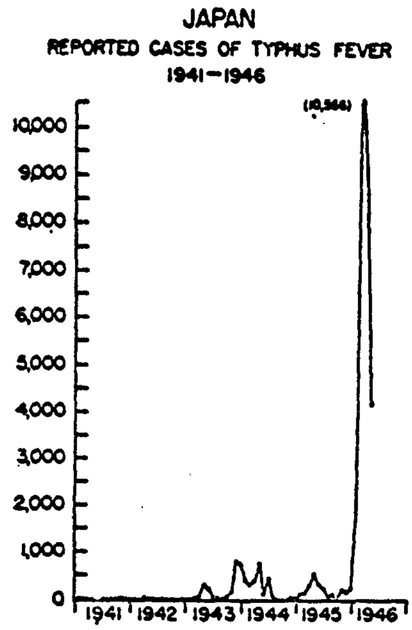
43/ See Preventive Medicine in World War II, Vol. 7, Office of the Surgeon General, Department of the Army, Washington, D. C., 1964, pp. 175-274. At the Belsen prison camp, typhus cases among the inmates stopped abruptly 14 days after the first delousing had been completed soon after the camp was taken by the British on April 5, 1945. Initially, practically 100 percent of the inmates were heavily infested with lice, and after the first delousing approximately 25 percent still had lice.

44/ Maxcy, *op. cit.*



Source: A. B. Scoville, Jr., "Epidemic Typhus Fever in Japan and Korea," Rickettsial Diseases of Man, F. R. Moulton, ed., American Association for the Advancement of Science, Washington, D. C., 1948, pp. 28-35.

Fig. 6. Reported cases of typhus fever in Japan from 1941 through May 1946.

producing several generations during the year. It has been observed[45/] that the only limitation on a breeding season's population of these mosquitoes would be the availability of larval sites, and that population might vary as much as 400-fold between seasons in one locality. Because these mosquitoes lay their eggs on the water surface and the adults tend to rest in sheltered places, no significant limitation by fallout radiation can be assured. However, danger to an individual during an encephalitis epidemic may be lessened by use of window screening, protective clothing, and avoidance of heavily infested areas at night. Thus information about the danger may be helpful in controlling the size of an epidemic.

45/ W. R. Horsfall, Mosquitoes, Tneir Bionomics and Re'ation to Disease, The Ronald Press Company, New York, 1955.

A threat from rabies might not depend on the increase of an animal population. Rather a threat might develop from the introduction of rabies into an existing susceptible population. If the vaccine protection of previously domestic cats and dogs were allowed to lapse as they roamed in a semiwild condition, rabies could become a threat through these normally friendly pets. A decrease in the resistance of wild animal populations could also result in outbreaks. However, unless urban populations were evacuated to the country, the contact with such wild populations would be minimal. In either type of outbreak, among semiwild cats and dogs or wild animals, a public informed of the danger would surely either avoid the area or destroy the offending animals which are not so secretive and are more obviously infected than hosts of the vectorborne diseases.

D. Parameters Affecting the Development of Vectorborne Diseases

Table VI summarizes the effects of several parameters on the spread of a vectorborne disease within the human population. Region is not considered to be a significant parameter in the development of rabies. Since dogs, cats, skunks, foxes, etc., are spread throughout the United States (and even though some areas have experienced almost no rabies in recent years--e.g., North Carolina), no firm reason could be found for assuming away the possibility of postattack threat.

Although the statistics indicate an age effect in susceptibility to mosquito-borne encephalitis (see Appendix A), the mechanism is not firmly established. Nutrition does not appear to affect the susceptibility to encephalitis or rabies.

Note that information on how to avoid danger or take precautions is important for all vectorborne diseases analyzed. According to Mr. Frank Prince and Dr. Leo Kartman,[46] information and instruction are perhaps the most important single factor in controlling plague. If the population is adequately informed of the plague danger, community action to avoid infested areas and to reduce rodent populations is enhanced. Also, it seems reasonable to assume that if information is broadcast that rabies is occurring in an area, people will avoid or destroy stray beasts rather than befriend or ignore them.

46/ L. Kartman and F. Prince, op. cit.

Table VI

PARAMETERS AFFECTING DEVELOPMENT OF VECTORBORNE DISEASE WITHIN HUMAN POPULATIONS

Human Population Parameter	Effect of Parameter	Spread of Vectorborne Diseases: Plague	Epidemic typhus	Mosquito-borne encephalitis	Murine typhus	Rabies
Region	Endemicity of Disease	*	*	*	*	–
	Environment Favoring Hosts and/or Vector	*	*	*	*	–
Age	General Health	*	*	?	*	–
	Development of Immunity	(not in U. S. Population)				
Nutrition	General Health	*	*	–	*	–
Information	Avoid Danger or Take Precautions	*	*	*	*	*
Crowding	Increase Spread through Closer Contact	**	**	–	–	–
Hygiene	Remove Vectors and/or Larvae from Body and Clothes	*	**	–	*	–
Radiation	General Health	*	*	–	*	–

* A definite effect of the parameter on the development of the disease.

** A large effect of the parameter on the development of the disease not in United States population.

Crowding can be very important in the spread of plague in the pneumonic form (more persons infected by each cough) and in the spread of epidemic typhus (lice require close contact for spread). Hygiene is also important in combating epidemic typhus; relatively simple hygienic measures[47/] kill the lice.

47/ See Table XV on page 66.

Radiation is postulated to have effects similar to poor health caused by malnutrition; the effects of radiation and nutrition on relevant body defense mechanisms are compared in Table VII.

Table VII

COMPARISON OF EFFECTS OF RADIATION AND MALNUTRITION

Defense Mechanisms of the Body	Effect of [a/] Radiation	Effect of [b/,c/,d/] Malnutrition
Killing of Microorganism by Phagocytosis	Decreased	Decreased
Antibody Response	Depressed	Depressed
Innate Antibodies	Depressed	Depressed
Defense Against Toxins	Decreased	Decreased
Interaction of effects	Unknown	Markedly synergistic

a/ W. H. Taliaferro, et al., Radiation and Immune Mechanisms. New York: Academic Press, 1964.

b/ N. S. Scrimshaw, et al., "Interaction of Nutrition and Infection," American Journal of Medical Sciences, 1959, pp. 237, 367-403.

c/ W. A. Janssen, et al., "The Relationship Between the Plague Bacillus and the Phagocytic Defense System of the Host," Bact. Proc., 1963, p. 80.

d/ K. F. Meyer, "Immunity in Plague: A Critical Consideration of Some Recent Studies," Journal of Immunology, (1950), pp. 139-163.

It is well known that different strains of bacteria may have varying virulence. However, no method of predicting changes in the postattack period was found; and therefore this effect was not investigated further.

E. Nonfatal Illness

The patient is not a productive member of society for a period of time even though a disease does not terminate with a fatality. Thus, manpower losses resulting from nonfatal cases were estimated by comparing the "best" estimates of the recovery period with the "best" estimates of mortality rates without explicitly considering the personnel required to care for patients. To translate the recovery time to percent of potential manpower loss, it is first assumed that the incidence rate is uniform across the population. It is recognized that workers might be more exposed (e.g., to plague transfer from rats harbored in debris being cleared), but this more refined analysis has not been attempted. Thus, percent days of illness of the surviving population is taken to represent the loss in addition to loss by death.

The percent of the manpower loss in the first year postattack is given by:

$$\left(\frac{\text{Days of illness per case}}{\text{Days per year}}\right) \times \left(\text{Total cases}\right) \times \left(1 - \begin{matrix}\text{Mortality}\\ \text{rate}\end{matrix}\right) \; 100 = \begin{matrix}\text{Percent days of}\\ \text{illness}\end{matrix} \qquad \text{(Eq. 3-3)}$$

Since the time lost by persons who are not killed by the vectorborne disease is the quantity desired, the mortality rate is subtracted. This relation may also be written as follows:

$$\left(\frac{\text{Recovery time}}{\text{365 days per year}}\right) \times \left(\text{Percent of cases} - \text{Percent of deaths}\right) = \begin{matrix}\text{Percent days of}\\ \text{illness}\end{matrix} \qquad \text{(Eq. 3-4)}$$

Table VIII shows the comparison of these "best" estimates.

Table VIII

BEST ESTIMATES OF RECOVERY TIMES AND MORTALITY RATES

Vectorborne Diseases	Days Required for Recovery*		Percent Mortality Rate	
	with antibiotics	without antibiotics	with antibiotics	without antibiotics
Plague: bubonic	21	75	5-20	60-90
pneumonic	21	——	5-70	100
Epidemic Typhus: louseborne	21	75	0	< 10 - > 40
Murine Typhus: fleaborne	15	30	0	2
Encephalitis: western equine	> 7-10	> 7-10	0	0
eastern equine	> 7-21	> 7-21	100	100
St. Louis	> 7-10	> 7-21	20**	20**

* Only days of acute illness counted,

** Fatality among reported cases,

a/ Cecil-Loeb, Textbook of Medicine, P. B. Beeson & W. McDermott (eds.), 11th ed. Philadelphia: W. B. Saunders Company, Ltd., 1959.

b/ T. M. Rivers and F. L. Horsfall, Viral and Rickettsial Infections of Man, 3rd ed. London: Petman Medical Publishing Company, Ltd., 1959.

c/ F. H. Top, Communicable and Infectious Diseases, 5th ed. St. Louis: The C. V. Mosby Company, 1964.

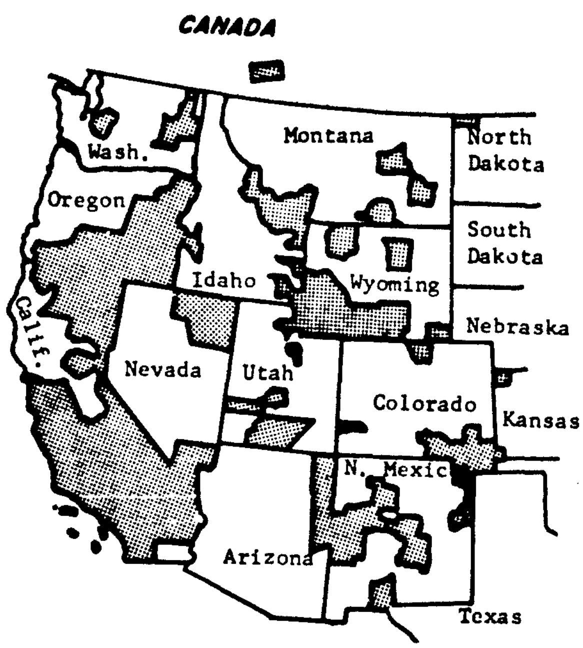
For the present analysis, regional effects on endemicity of the infectious organism and environment conducive to disease spread are of particular importance because these are stable relationships. The eradication of a focus of infection is expensive and time-consuming. Thus, the situation with respect to endemicity may improve, but improvement would occur slowly. In the United States today much effort is devoted to limiting the spread of diseases such as plague, and the demographic phenomena affecting epidemic typhus change slowly so that unfavorable spread may also be assumed to occur slowly, if at all. The following section develops the idea of regional risk in the United States for the five diseases.

IV. REGIONS "AT RISK" IN THE UNITED STATES

It has been argued that if postattack command and control over the movements of people exists, the risk of vectorborne disease will be confined to the area of endemicity. Definition of areas of endemicity must also consider the potential free range of other hosts. In this analysis, this expanded definition is applied to data and estimates of present endemicity. The results are used to outline the section of the country and the fraction of the postattack population "at risk" from each of five diseases. Also, in this analysis, the postattack population is assumed to be distributed the same as the preattack population.

A. Plague

Plague is currently endemic in numerous wild (sylvatic) rodent populations in Western United States (see Appendix B). Figure 7 shows that in 1945 sylvatic plague was almost exclusively confined to California, Oregon, Washington, Idaho, Nevada, Arizona, Utah, Montana, Wyoming, Colorado, and New Mexico. Since 1950, all recorded



Source: K. F. Meyer, "The Prevention of Plague in the Light of Newer Knowledge," Annals of the New York Academy of Science, Vol. 48 (1941-47) pp. 429-467.

Fig. 7. The Extent of Sylvatic Plague in the United States of America and Canada by the Middle of 1945. (Countries where sylvatic plague has been demonstrated by examination of squirrels, marmots, prairie dogs, etc., and their ectoparasites.)

cases of plague in humans have originated in these Western states.[48] The distribution of plague among rodents in the eleven states is very scattered. Thus, under the assumptions of this analysis, the plague threat will not be underestimated if the entire population of these eleven states is taken to be at risk. Furthermore, in 1960, the population of these states was approximately 31 million while the population of the nation was approximately 179 million. Therefore, approximately 17 percent of the national population would be "at risk" from plague.

B. Epidemic Typhus

The last outbreak of epidemic typhus in the United States occurred in 1915 among the Navajo Indians.[49] In the absence of importation (assumed not to occur), an initial focus of epidemic typhus would have to be a case of Brill-Zinsser disease, which is a recrudescence of epidemic typhus and, although rare, has most often been found in the United States among foreign-born Jews.[50]

The Jewish population of the United States, almost 100 percent urban,[51] is concentrated in the Northeast region of the United States. Conditions favoring the development of epidemic typhus are crowding, weather requiring heavy clothing, lack of hygiene, and the possible coincidental effects of famine. Because of the dense population, and the relatively severe climate as well as the inference that most--if not all--potential foci reside there, the urban population of Virginia, Kentucky, and all states north of them and east of the Mississippi River were taken to be "at risk" from epidemic typhus in a postattack period. The total population was approximately 70 million in 1960. Thus, approximately 39 percent of the population would be "at risk" from epidemic typhus.

C. Mosquitoborne Encephalitis

Figure 8 shows the extent of historical incidence of the three types of mosquitoborne encephalitis of importance in the United States. Superposition of the maps in Figure 8 shows that in the past many large population centers of the Northeast have not been greatly affected by any of the three forms of mosquitoborne encephalitis. However, host sources of the encephalitides (the infectious organisms of mosquitoborne encephalitis) may be migratory birds with normal flight ranges of several

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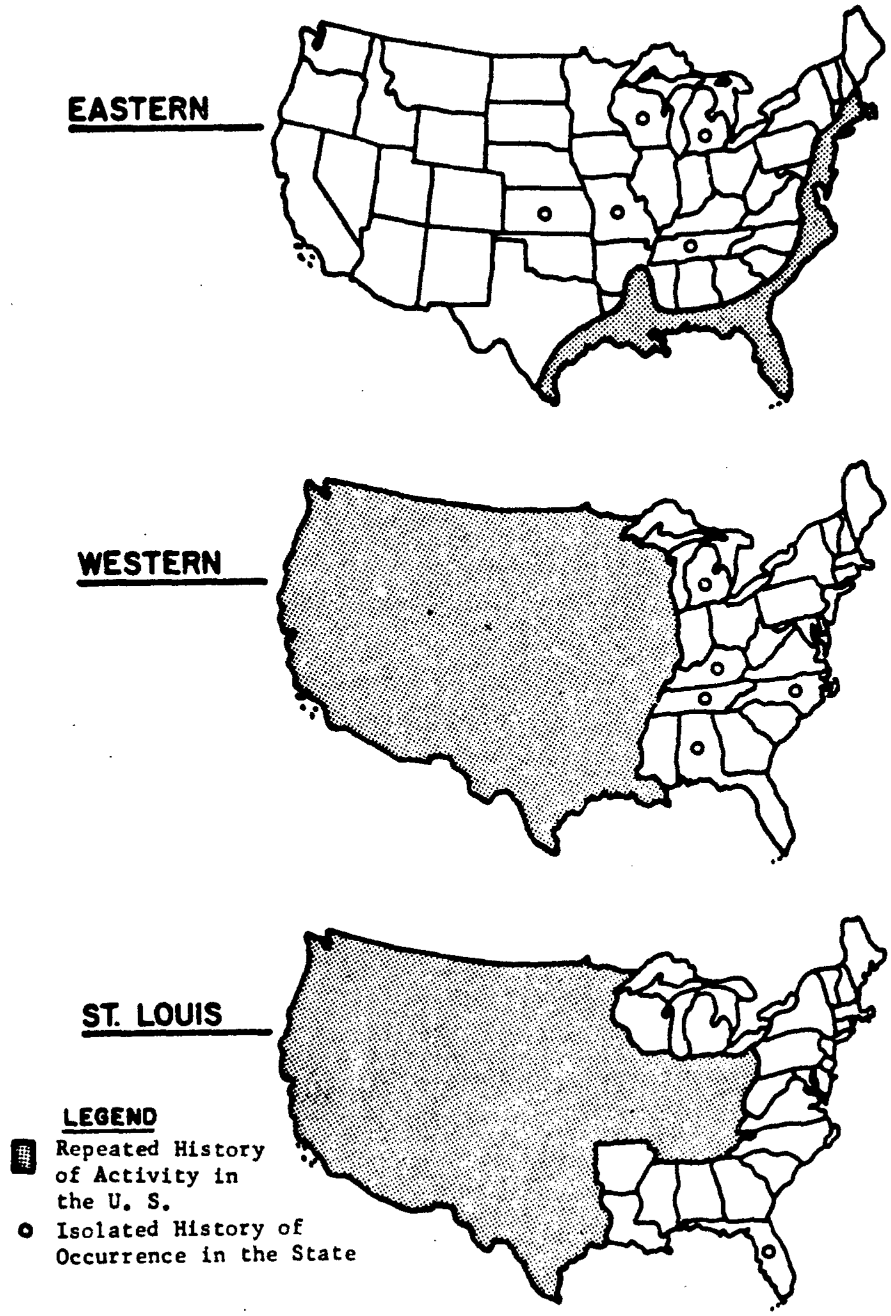
48/ Kartman, et al., op. cit.

49/ Maxcy, op. cit., p. 424.

50/ Ibid.

51/ N. Glazer, American Judaism. Chicago: The University of Chicago Press, 1957. The migration of the Jewish population has mainly been to higher cost districts or the suburbs rather than anything like the western movement which was essentially complete before the arrival of the bulk of the eastern European Jewish immigrants.



Source: Communicable Disease Center Reports, Public Health Service, USDHEW.

Fig. 8. Geographical Distribution of the Arthropodborne Encephalitides in the United States. (Total Virus Activity in Man and Animals)

hundred miles. Allowing for postattack disturbance of migratory habits and flight paths, no region can be assumed to be free of a threat from mosquitoborne encephalitis.

Even the relatively small areas affected by the eastern encephalitis which has occurred only in small outbreaks and almost entirely in rural areas, cannot be excluded because all regions are within range of migratory birds carrying the encephalitis from other regions with a history of mosquitoborne encephalitis. Thus, 100 percent of the population would be "at risk" from mosquitoborne encephalitis.

D. Murine Typhus

Figure 9 shows the distribution of reported cases of murine typhus (endemic fleaborne) in the United States during the peak years of 1941-47. Although not clearly shown in the figure, counties with large numbers of cases were located in southwestern Georgia and southeastern Alabama. In recent years, the total number of cases in the United States has drastically decreased. Endemicity is assumed only for North Carolina, Tennessee, South Carolina, Georgia, Alabama, Florida, Mississippi, Louisiana, Arkansas, Texas, and Oklahoma. The total population of the eleven states was approximately 42 million in 1960. Thus, approximately 23 percent of the population would be "at risk" from murine typhus.

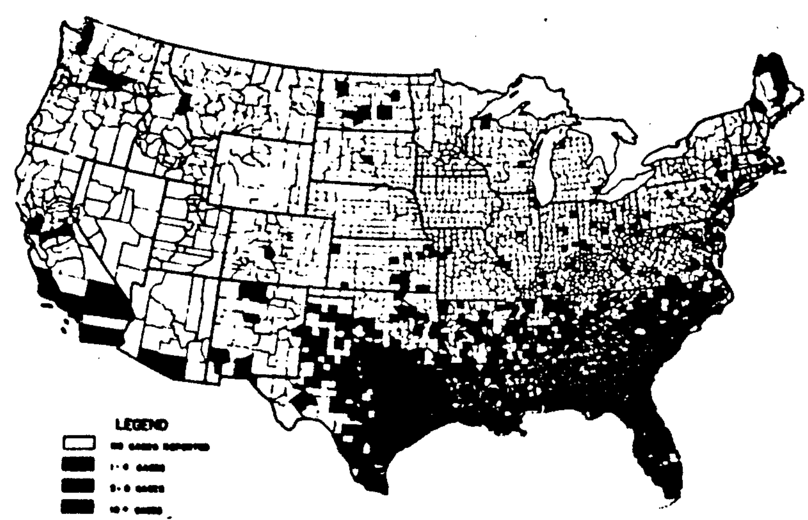


Fig. 9. Reported Cases of Endemic Typhus Fever in the United States, 1941-1947.

E. Rabies

Rabies is endemic in wild animal populations in all areas of the United States. Some areas have had low incidences of reported cases of animal rabies while other areas have had higher incidences. Endemicity, even though resulting in low preattack incidence of animal rabies, poses the threat of a postattack outbreak.

Consequently no basis was established for regional differentiation of the rabies threat; 100 percent of the population would be "at risk" from rabies.

Although no regional risk was established for mosquitoborne encephalitis or rabies, it will be shown below that consideration of the regional risk for plague, epidemic typhus, and murine typhus significantly affects the estimates of the postattack threat from vectorborne diseases.

V. COMPARISON OF THE POSTATTACK THREATS FROM VECTORBORNE DISEASES

The potential threats from vectorborne diseases are compared in Table IX. Titchen's[52] three-factor model (Eq. 1-1; p. 5) was used in evaluating plague and epidemic typhus as well as the alternative three-factor model (Eq. 2-1; p. 14). At present, the other diseases (mosquitoborne encephalitis, murine typhus, and rabies) seem amenable only to the alternative model. When only a small number of occurrences of a rare event are observed (e.g., cases of plague in McKinley County, New Mexico) little confidence can be attached to estimates of probabilities derived from the data. However, when such estimates agree fairly closely with "expert judgements", at least intuitive credence is lent to both estimates. The results of these calculations are presented in Table IX.

A. Plague

In Titchen's row of Table IX, the percentages of cases and deaths from plague under the uniform risk column were extracted from his work; the manpower loss and all of the values under the regional risk column were obtained by applying Eq. 3-3 for manpower loss and multiplying by 0.17 to transform the results reported by Titchen. Thus, percent days of illness from nonfatal cases besides the loss of life from the disease is given by

$$\left(\frac{75}{365}\right) (6.3\% - 3.15\%) = 0.65\%$$

for uniform risk; regional risk is obtained by multiplying by 0.17 since 17 percent of the population would be "at risk" from plague according to the regional risk hypothesis.

Likewise, in the McKinley County row, the percentages for plague were obtained by applying Titchen's method. Estimates of expected epidemic size (given an initial case) and mortality estimates were those used by Titchen. The probability of an initial case was derived from the data for McKinley County, New Mexico. A "community" of 20 thousand persons was assumed in the McKinley and Titchen's calculations.

The McKinley County outbreak (1965) was the largest in the United States from 1956 to 1965.[53] In that outbreak, seven cases occurred in a population of approximately 38 thousand. Thus, each individual had a probability of $7/38{,}000 = 1.8 \times 10^{-4}$ of having bubonic plague; one of these cases developed the pneumonic complication.

52/ Titchen, *op. cit.*

53/ Kartman, *op. cit.*

Table IX

COMPARISON OF POTENTIAL THREATS FROM VECTORBORNE DISEASES

Vectorborne Diseases	Basis of Evaluation	Percent of Population Threatened					
		Uniform Risk			Regional Risk[a]		
		Cases	Deaths	Days Loss[b]	Cases	Deaths	Days Loss
Plague	Titchen's analysis[c]	6.30	3.15	0.65	1.10	0.55	0.11
	McKinley County, New Mexico,[d] applied to Titchen's analysis	12.6	6.30	1.30	2.20	1.10	0.22
	Canton, China (1894)[e]	-	7.0	-	-	1.2	-
	India (early 1900's)[f]	-	0.516	-	-	0.08	-
Epidemic Typhus	Titchen's analysis[g]	0.054	0.016	0.0078	0.021	0.006	0.0031
	$\frac{1}{1,000,000}$ Brill-Zinsser cases in urban North-eastern U. S.[h] applied to Titchen's analysis	0.22	0.065	0.032	0.085	0.025	0.012
	Russia (1917-1921)[i]	3.6	0.43	0.65	1.4	0.167	0.25
	Ireland (1816-1819)[j]	2.9	-	-	1.1	-	-
	U. S. Civil War [k]	(Few)	(Few)	-	-	-	-
Mosquitoborne Encephalitis	St. Louis, Missouri (1933)[l]	0.15	0.03	0.01	0.15	0.03	0.01
	St. Louis x 2 [m]	0.3	0.06	0.02	0.3	0.06	0.02
Murine Typhus	Grady County, Georgia (1946)[n]	0.2	0.006	0.02	0.07	0.0014	0.0056
	Coffee County, Alabama (1943)[o]	0.66	0.013	0.053	0.155	0.0031	0.0125
Rabies	Yearly treatments in United States[p]	0.017	0.017	-	0.017	0.017	-

a/ See section III.C for explanation.
b/ See section III.B for estimation.
c/ Titchen, op. cit.
d/ Kartman, op. cit., see section III.D.1 for discussion.
e/ Meyer, op. cit.
f/ Ibid.
g/ Titchen, op. cit.
h/ Voors, op. cit., see section III.D.2 for discussion.
i/ Zinsser, op. cit.
j/ Ibid.
k/ Ibid.
l/ Maxcy, op. cit.
m/ See section III.D.3 for discussion.
n/ Love, op. cit.
o/ Hill, op. cit.
p/ Maxcy, op.cit., See section III.D.5 for discussion.

Since radiation and stress of a postattack period might double the conversion rate of bubonic to pneumonic, 25 percent is deemed a reasonable estimate of the probability of a bubonic developing into a pneumonic case.[54/] The probability of having at least one case of pneumonic plague in a community of 20,000 is approximately 1 - 0.4 = 0.6, based on the McKinley County experience. This is twice the probability of an initial case assumed in Titchen's calculations; thus, all numbers in the second row are twice those in the first.

The outbreaks of plague in Canton, China, and in India were chosen for analysis because the efficacious drugs were unknown and knowledge of the vectors was very limited. These two outbreaks are cited in several references as "scare" examples; they are thus assumed to yield estimates of maximum threats.

In 1894 there were 80-100 thousand deaths in Canton[55/] out of a total population of approximately 1.5-2.0 million.[56/] In Canton the highest mortality rate implied by these numbers 100,000/1,500,000 = 0.07. In India the mortality rate is quoted as 5.16 per 1,000 per year at the peak of the epidemic during the early years of the twentieth century.[57/] These figures show approximately a factor of 10 range in the estimate with the figure based on Titchen's work in the middle of this range. When corrected for regional risks, Titchen's number might be taken as a "best" estimate of the risk from plague in the postattack period if no preattack preparations were made.

B. Epidemic Typhus

The first row of the epidemic typhus section (Table IX) gives Titchen's estimates under the uniform risk column. Since approximately 39 percent of the population would be "at risk" from epidemic typhus, the figures under the regional risk column are 0.39 times the corresponding figures in the uniform risk column.

For all rows of the epidemic typhus section, manpower loss is computed by using 75 days lost per case out of 365 days of the year.

54/ As noted above only the penumonic form, which spreads man-to-man, can be reasonably represented by Titchen's model. The bubonic form which occurs as sporadic cases transferred from an epizootic does not fit the logic of that model. A total probability of $(.25)\ (1.8 \times 10^{-4}) = 4.25 \times 10^{-5}$ is an estimation that an individual will be an initial case of pneumonic plague. Then the probability of having no cases in a community of 20 thousand is $(1 - (4.25 \times 10^{-4}))^{20,000}$. By Poisson's approximation to the binomial distribution, the probability of having no pneumonic plague cases in a community of 20,000 is approximately $20,000\ (4.25 \times 10^{-5}) = 0.4$.

55/ Meyer, "Plague," op. cit., p. 472

56/ Encyclopedia Britannica, 11th ed., 1910-1911, Vol. 5, p. 220.

57/ Ibid.

The second row of estimates was derived the same as the first except for the probability of an initial case. It was estimated[58] that in the urban Northeastern United States, one out of one million persons would be a Brill-Zinsser patient in the first year postattack; thus, the probability that an individual would not be a Brill-Zinsser patient is $(1 - 10^{-6})$. The probability of not having a single Brill-Zinsser case in a "community" of 20 thousand persons is $(1 - 10^{-6})^{20,000}$. The same type approximation used in the plague analysis yields a probability of approximately 0.02 that there will be at least one case of Brill-Zinsser disease in a "community" of 20 thousand. In Titchen's analysis the estimate of this probability was 0.005; thus, the numbers in the second row are 4 times the numbers in the first row.

As expected, the primary data on Russian population and deaths for 1917-21 are scant. However, extensive demographic analyses and expert inferences give credence to estimates of typhus cases and mortality. Out of an initial population of approximately 140 million [59] in 1917, 25 million cases and 2.25-3.00 million deaths were estimated from the disease from 1917-1921.[60] An average figure of 5 million cases and 600 thousand deaths per year out of 140 million give rates of 3.6 percent cases and 0.43 percent deaths per year.

The uniform risk column for Russia's row gives the average percentages under the assumption that conditions could be as uniformly adverse in the postattack United States as they were in postrevolution Russia. Again the regional risk column applies the factor of 0.39 to the quantities in the uniform risk column.

Zinsser[61] notes that during the famine years 1816 to 1819 there were no less than 700 thousand cases of epidemic typhus among the 6 million inhabitants of Ireland. This was an average rate of approximately 175 thousand cases per year, or 2.9 percent. The fatality figures for this epidemic were not found, but the case rate agrees closely with the case rate during the Russian epidemic from 1917 to 1921.

Zinsser also notes that epidemic typhus was not a problem during the U. S. Civil War even in prison camps where conditions were the worst.

58/ Dr. A. W. Voors (personal communication). This "best" estimate by Dr. Voors was made independently from the estimate made by a different consultant in Titchen's work. The previous estimate was a direct estimate of the probability of an initial case.

59/ F. Lorimer, The Population of the Soviet Union, History and Prospects, The League of Nations, Geneva, 1940. A 1914 population estimate of 140,405,000 is given on page 36 and the deaths from typhus are estimated on page 41; also an estimate of deaths from typhus in the year 1920 is given.

60/ H. Zinsser, Rats, Lice and History. Boston: Little, Brown, and Company, Inc., 1935.

61/ Ibid.

C. Mosquitoborne Encephalitis

The largest single epidemic of mosquitoborne encephalitis occurred in St. Louis, Missouri (1933). Approximately 1,100[62] cases of St. Louis encephalitis occurred with a case rate of approximately 0.15 percent. The mortality rate approached 20 percent of the reported cases.[63] Since regional risks were not differentiated, the regional risk and uniform columns of Table IX contain the same values. The illness loss was computed by using 30 days lost per case out of 365 days.

Although the specific cause of St. Louis encephalitis was not known at the time of the St. Louis epidemic, it might be argued that general measures for comfort, sanitation, and fly control (e.g., window screens, water drainage, etc.) may have contributed to the cont ol of encephalitis. These measures would probably be applied to a lesser extent in the postattack period unless plans were made. Increasing the St. Louis values by a factor of two might account for this effect. However, the contention of Engineering-Science, Inc., seems reasonable--i.e., because of the reduction of domestic poultry in cities, the St. Louis rates give a definite upper bound to the potential postattack rate.[64]

D. Murine Typhus

Estimates of the upper limits of the potential threat from murine typhus were obtained from two well-documented occurrences of murine typhus during the period of peak incidence (middle 1940's) in the United States and in the region of maximum occurrence (Georgia-Alabama-Florida). Although higher case rates may have occurred, no higher rates were found in published literature.

The two occurrences were in Grady County, Georgia (1946)[65] and Coffee County, Alabama (1943)[66]. In Grady County a maximum rate of 290 cases per 100 thousand (0.29 percent) was reached; in Coffee County 211 cases were reported out of a population of approximately 32 thousand (0.66 percent). Although there were few deaths (only two in Coffee County), the estimated untreated mortality rate of 2 percent of reported cases was applied to obtain the percentages of deaths. The regional risk values were obtained using a factor of 0.235. The percentage illness loss was computed by using 30 days lost per case out of 365 days.

62/ Maxcy, op. cit., p. 376.

63/ Ibid.

64/ Engineering-Science, Inc., op. cit., p. 76.

65/ G. J. Love and W. W. Smith, "Murine Typhus Investigation in Southwestern Georgia," Public Health Reports, Vol. 75 (May 1960), pp. 429-440.

66/ E. L. Hill and S. C. Ingraham, II, "A Study of Murine Typhus Fever in Coffee County, Alabama," Public Health Reports, Vol. 62 (1947), pp. 875-881.

E. Rabies

The Pasteur prophylactic treatment has reduced the occurrence of rabies among humans to a few cases per year. Because of the fear of rabies and because treatment is recommended if the suspected animal is not recovered, more persons receive the Pasteur treatment than are actually exposed. Approximately 30 thousand persons receive rabies vaccine each year in the United States.[67] Only 10 percent or less of the persons actually bitten by rabid animals would be expected to contract rabies.[68] Thus increasing the number of persons bitten by a factor of 10 would cause fewer than 30 thousand deaths without treatment.[69] The 30 thousand per 180 million (0.017 percent) is an upper limit for the potential threat from rabies.

The threats from the five diseases are summarized and compared in the following section.

F. Summary of Postattack Threats

The main results of the threat analysis are presented in Table IX. It is seen that for plague and epidemic typhus the reworked parameters and estimates from historical incidences bracket the estimates made in an earlier study which was not specifically concerned with vectorborne diseases.[70] Applying the concept of regional risk does not materially affect the ranking within this set of diseases by importance from that which would be obtained with the uniform risk data. On all accounts, plague presents the major national threat among the set of vectorborne diseases (a similar conclusion was reached more intuitively by Mitchell[71]). If the Russian and Irish epidemics are taken as "best" estimates, epidemic typhus would rank as the second most important vectorborne disease threat. If, on the other hand, Titchen's estimates are weighted more heavily, epidemic typhus is of the same order of importance as encephalitis, murine typhus, and rabies. On the basis of death, murine typhus is of least importance; on the basis of cases, rabies is of least importance among the five diseases.

67/ Maxcy, *op. cit.*, p. 542.

68/ *Ibid*, pp. 544-545.

69/ *Ibid*., p. 546. It should be noted that cauterization of the bite with nitric acid (or even iodine or green soap) offers some protection.

70/ Titchen, *op. cit.*

71/ Mitchell, *Plague*..., *op. cit.*; and Mitchell, *Survey*..., *op. cit.*

In the comparisons of total regional risks, the most severe estimate indicates approximately 4.0 percent of the population would have a vectorborne disease and 1.35 percent of the population would die from one of the five diseases during the first year postattack. The least severe estimates indicate the cases and fatalities would be approximately 0.34 and 0.16 percent [72/] respectively. From these data a "best" estimate might be given as 2.00 percent cases and 0.75 percent fatalities due to all five diseases. Plague might account for one-half the cases and two-thirds of the deaths from vectorborne diseases. Epidemic typhus and mosquitoborne encephalitis would follow in that order of importance, while murine typhus would rank fourth on the basis of cases, and rabies would rank fourth on the basis of deaths.

The "best" estimate indicates that vectorborne diseases are a potential postattack health problem (0.75 percent of 100 million survivors is 750,000 potential deaths). However, in comparison with the enteric disease threat estimated in previous studies,[73/] the vectorborne disease threat is an order of magnitude less than the postattack threat from the combination of enteric and man-to-man diseases.

Comparison of the risks from plague and epidemic typhus calculated for regional risk under the assumptions of this analysis and the corresponding risks calculated for uniform risk across the nation indicate the importance of plans to control population movements and disseminate information if epidemics occur.

72/ In the least severe summations the plague cases were taken at 0.80 percent; the lack of typhus during the Civil War was not considered in the summation.

73/ Titchen, op. cit.; Engineering-Science, Inc., op. cit.; and Hallan, et al., op. cit.

VI. RODENT AND RODENT ECTOPARASITE CONTROL MEASURES

Since the study is concerned with the control of both commensal (domestic) and wild rodents, this section is divided into those subtopics. An additional subtopic is miscellaneous control measures; it introduces measures only rarely employed in the control of commensal and wild rodents.

A. Control Measures for Commensal Rodents

The adjective commensal applies to rodents which live in close proximity to man and are, in fact, dependent on man's activities for survival. The commensal rodents of concern in the transmission of plague and murine typhus are the brown rat, *Rattus norvegicus*, and the black rat, *Rattus rattus*.

1. Effectiveness Measure. Increases in a postattack rat population y have been estimated as multiples of a preattack population x by assuming that there are: increased food and harborage, no weapon effects on the rat population, and inadequate countermeasures.

In Table X, increase rates of 3 and 10 percent per week were used to calculate the 'best' and 'extreme' estimates, respectively. The 3 percent rate corresponds to sewer rats and the 10 to rats living in a corn crib.[74] Accordingly, in the table, the 'best estimate' of a rat population 24 weeks postattack is a twofold increase.

Table X

ESTIMATED RAT POPULATIONS AT SELECTED TIMES POSTATTACK

Countermeasures	Preattack Population	Postattack Population, y			
		Weeks Postattack			
		4	8	12	24
Adequate	x	x	x	x	x
Inadequate					
Best Estimate	x	1.1x	1.3x	1.4x	2.1x
Extreme Estimate	x	1.5x	2.2x	3.3x	11.0x

Thus, the population difference between adequate and inadequate countermeasures provides an effectiveness measure for postattack rodent control operations.

74/ E. W. Bentley, A. H. Bathard, and J. D. Riley, "The Rates of Recovery of Sewer Rat Populations After Poisoning," Journal of Hygiene, Vol. 57, No. 3 (1959), pp. 291-298.

Postattack population y may be less than preattack population x due to destruction by fire as reported for the incendiary bombing of Japanese cities[75]. In this case (y < x) the effectiveness measure differs from that in Table I. It is presumed that even with 'adequate' countermeasures, the population would grow back toward the preattack level x since that level represents "near-maximal" (peacetime) control. For example, 8 to 24 weeks might elapse before the preattack level was regained if the rat population of an area was reduced uniformly by a factor of 2. With 'inadequate' countermeasures the population may grow toward an equilibrium >x; in this case the values of Table I are applicable.

2. Time Constraints for Application of Rodent Control Measures. A recent study[76] states that at least one month of lag time is available postattack before rodent control measures are required. The data presented in Table I are not only consistent with that statement but also suggest that the time lag may be several months in the absence of a disease threat. (Presence of rats does not, per se, imply an impending plague or murine typhus outbreak.) Therefore, the decision to activate postattack rodent control measures may await identification of a disease threat.

3. Control Measures. Common control measures for commensal rodents include trapping, fumigation, ratproofing, and poisoning by ingestants. In this section these four approaches to the control of commensal rodents are examined and evaluated in terms of their usefulness for postattack operations.

a. Rodenticides. Rodenticides, which are ingestant poisons, fall into two main categories: the quick-killing, or one-shot, agents and the anticoagulants, which must be ingested over a period of several days for lethal effects. Current rodent control practice in the United States favors the use of the anticoagulant poisons. Some rodenticide characteristics which explain this preference are cited below. These and other characteristics of common ingestant rodenticides are shown in Table XI.

75/ U. S. Strategic Bombing Survey, The Effects of Bombing on Health and Medical Services in Japan. Washington, D. C.: U. S. Government Printing Office, 1947.

76/ Engineering-Science, Inc., *op. cit.*

Table II

CHARACTERISTICS OF COMMON RODENTICIDES AND RODENTICIDAL BAITS

Rodenticide Characteristics										Bait Characteristics						Safety Characteristics			
						Solubility							Type of Mixtures			Relations to Humans and Other Animals			
Rodenticide	Lethal Dose (mg/kg)	Cumulative	Toxic Effect	Tolerance Developed	Degree of Effectiveness	Water	Oil	Odor	Taste Objectionable to Rat	Acceptance	Reacceptance	Rodenticide Deterioration in Baits	Dry	Fresh	Water	Secondary Poisoning	Absorbed Through Skin	Degree of Hazard in Use	Antidotes
ANTICOAGULANTS Warfarin Pumarin Pivel	1	YES	Inhibits clotting of blood, causes internal hemorrhages; slow acting.	NO	GOOD	YES	YES	NONE	SLIGHTLY	GOOD	GOOD	NONE	YES	NO	YES	YES	NO	SLIGHT	Vitamin K and transfusions of whole blood.
ANTICOAGULANT Diphacinone	0.3	YES	Same as Above	NO	GOOD	NO	YES	NONE	SLIGHTLY	GOOD	GOOD	NONE	YES	NO	NO	NO	YES	SLIGHT	Same as Above
ANTICOAGULANT PMP	5.0	YES	Same as Above	NO	GOOD	NO	YES	NONE	SLIGHTLY	GOOD	GOOD	NONE	YES	NO	NO	NO	NO	SLIGHT	Same as Above
ANTU[a]	6	NO	Pleural effusion (overproduction of fluid in the lungs), slow acting.	YES	GOOD	NO	NO	SLIGHT	MODERATELY	GOOD	POOR	SLIGHT	YES	YES	NO	NO	NO	MODERATE	NONE
ARSENIC	100	NO	Kidney destruction, gastroenteritis. Central nervous system affected, slow acting.	YES	FAIR	YES	NO	NONE	MODERATELY	FAIR	FAIR	NONE	NO	YES	YES	NO	NO	MODERATE	Milk of magnesia, milk and water, oxide of iron
PHOSPHORUS, Yellow	1.7	NO	Heart paralysis; gastro-intestinal and liver damage; fast acting.	NO	GOOD	NO	YES	STRONG	STRONGLY	GOOD	FAIR	FAST	YES	NO	NO	NO	NO	MODERATE	Copper sulfate before emetic; cathartic and water. Avoid fats and oils (as milk).
RED SQUILL[a]	500[b]	NO	Heart paralysis; slow acting.	NO	FAIR	YES	YES	MEDIUM	STRONGLY	FAIR	POOR	MEDIUM	YES	YES	YES	NO	NO	SLIGHT	Acts as own emetic to animals capable of vomiting.
SODIUM FLUOROACETATE (1080)	5(Norway) Rat / (Roof) Rat	NO	Paralysis of heart and the central nervous system, fast acting.	NO	GOOD	YES	NO	NONE	SLIGHTLY	GOOD	GOOD	SLIGHT	NO	YES	YES	YES	NO	EXTREME	NONE. Monoacetin or ethyl alcohol and acetic acid recommended.
THALLIUM SULFATE	25	YES	Gastro-intestinal hemorrhage, kidney and endocrine damage, respiratory failure, slow acting.	NO	GOOD	YES	NO	NONE	SLIGHTLY	GOOD	GOOD	NONE	YES	YES	YES	YES	YES	EXTREME	NONE. Sodium iodide and sodium thiosulfate recommended.
ZINC PHOSPHIDE	40	NO	Heart paralysis, gastro-intestinal and liver damage, fast acting.	NO	GOOD	NO	YES	STRONG	STRONGLY	GOOD	GOOD	FAST	YES	YES	NO	NO	NO	MODERATE	Copper sulfate before emetic, cathartic and water. Avoid fats and oil (as milk)

a/ Effective against Norway Rats only.

b/ Minimum acceptable level, more toxic squills give better results.

Source: J. H. Johnson and B. F. Bjornson, *Rodent Eradication and Poisoning Programs* (*Training Guide-Rodent Control Series*), Atlanta: USPHS, Communicable Disease Center, 1964.

(1) Comparative Toxicity. The lethal dose in milligrams of toxicant per kilogram of body weight is lowest for the anticoagulant rodenticides; among the one-shot agents, only sodium fluoroacetate approaches that toxicity, as shown in Table XI. Another aspect of toxicity is the biological activity spectrum. All anticoagulant rodenticides listed in Table XI are effective against both roof and Norway rats; among the quick-kill rodenticides arsenic, yellow phosphorus, sodium fluoroacetate, thallium sulfate, and zinc phosphide are effective against both species, with ANTU and red squill affecting only the Norway rat.

(2) Bait Acceptance. Apparently, baits treated with either anticoagulant or quick-kill rodenticides are initially equally acceptable to rodents. However, ingestion of sublethal quantities of quick-kill rodenticides results in bait-shy animals.[77] The use of anticoagulant rodenticides eliminates the bait reacceptance problem since the animal is apparently unaware that it is ingesting a cumulative poison.

(3) Bait Formulation. Suggested bait formulations are given in Table XII. Anticoagulant poisons do not require fresh bait and may be prepared with corn meal, rolled oats, or other grains. Another advantage is that a bait prepared with grain because it is not particularly attractive to cats, dogs, other domestic animals, or children reduces the problem of accidental poisoning. Still another advantage is that the sodium salt of many anticoagulant compounds is water soluble, permitting water to be used as the vehicle for the poison.

(4) Choice of Rodenticide. Current rodent control practice in the United States favors the use of anticoagulant poisons. This preference is based on a number of considerations including the following: there is no problem of bait reacceptance; the hazards to domestic animals and children is reduced; they may be safely used by unskilled personnel; they have a wide biological activity spectrum; and they offer ease of bait preparation.

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[77] B. F. Bjornson and C. V. Wright, Control of Domestic Rats and Mice (Training Guide - Rodent Control Series). Atlanta: USPHS, Communicable Disease Center (n.d.).

Table XII

SUGGESTED FORMULAS FOR RODENTICIDAL BAITS

RODENTICIDE	BAIT FORMULA: MATERIALS	PARTS BY WEIGHT	AMOUNT
ANTICOAGULANTS[a] Warfarin, pival, fumarin, diphacinone[b], PMP[b]	Poison (0.5% concentrate)	1	1 lb.
	Bait: Yellow corn meal	19	19 lb.
RED SQUILL	Poison (fortified)	1	1 lb.
	Bait: ground meat, bacon, canned fish, grains, cereals, or combination of these.	9	9 lb.
	Binder (optional) as required to hold bait together.		
ARSENIC TRIOXIDE	Poison (finely powdered)	3	3 oz.
	Bait: ground meat, bacon, fish, grains, cereals, or combination of these, and water.	96	6 lb.
	Binder (optional)		
	Tartar emetic	1	1 oz.
	Discoloring agent (optional)		
ZINC PHOSPHIDE[c]	Poison	1	4 oz.
	Bait: ground meat, bacon, canned fish, grains, cereals, or combination of these.	99	25 lb.
	Binder		
	Tartar emetic	1/3	1½ oz.

a/ Where rodents do not accept this formula, replace 7 parts of the yellow corn meal with 5 parts of rolled oats, 1 part of granulated sugar, and 1 part of corn oil. This mixture is more expensive but should increase acceptance by rodents. A discoloring agent, such as charcoal, may also be added.
Anticoagulants are available as water soluble baits. They should be mixed according to instructions on the label.

b/ Mix or use PMP and diphacinone according to directions on the label.

c/ Zinc phosphide is often used to coat ½-inch cubes of sweet potato or apple, as bait. To mix, swirl the freshly cut, moist cubes in a bucket with the poison, using a gentle motion, until all of the poison has been taken up by the cubes.

Table XII (Continued)

RODENTICIDE	BAIT FORMULA		
	MATERIALS	PARTS BY WEIGHT	AMOUNT
ANTU	Poison	1	1 lb.
	Bait: ground meat, bacon, canned fish, grains, cereals, or combination of these.	32	32 lb.
	Tartar emetic	1	1 lb.
SODIUM FLUOROACETATE (1080[d/]	Poison	——	$\frac{1}{3}$ oz.
	Bait: water	——	1 gal.

Note: Rats are attracted to sweets. A small amount of sugar, molasses, syrup, raisins, or sweetened fruits will increase acceptance when added to food or water baits.

d/ Sodium monofluoroacetate (1080) is still the most effective fast-acting rodenticide, but its extreme toxicity to man and animals requires that it be used only on certain types of premises and only by carefully trained crews. The precautions necessary for safe use of 1080 are numerous and involved. They are described in "Operational Memoranda on Economic Poisons" issued by the Communicable Disease Center.

Source: B. F. Bjornson and C. V. Wright, Control of Domestic Rats and Mice (Training Guide - Rodent Control Series). Atlanta: USPHS, Communicable Disease Center (n.d.).

A strong consideration for the use of anticoagulants following thermonuclear attack is the fact that radiation sickness decreases blood platelets essential to coagulation;78/ a decreased platelet count would likely enhance the effect of anticoagulants. Laboratory experimentation is indicated to test this possible second-order radiation effect.

Thus, the anticoagulants appear to be the rodenticides of choice for postattack control of commensal rodents.

b. Trapping. The following discussion of trapping as a means of rodent control is based largely on the writing of Pollitzer.79/

(1) Trap Types. In general, traps are of three types: arresting, enclosing, and killing. An example of the arresting trap is the steel bear trap. An enclosing trap uses a basket or trapdoor to surround the rodent; it is used when one wishes to examine a live animal for the presence of disease or to enumerate the fleas in residence. An example of the simplest killing trap is the common break-back mouse trap.

(2) Use of Traps. In considering the use of traps, the control worker should be aware of the following:

(a) Baited traps are most unattractive to rats when food supplies are plentiful.

(b) Baited traps are normally placed off of the rat runway, whereas unbaited traps must be located on the runway.

(c) The selection of bait is no problem since almost any kind of human food is acceptable to rats.

(d) A pretrapping session is often required to overcome the rats' fear of new objects.

(e) It may be necessary to camouflage traps with sacking, straw, etc.

(f) Break-back, or killing, traps must be secured.

78/ S. Glasstone, Sourcebook on Atomic Energy (2nd ed.). Princeton, N. J.: D. Van Nostrand Co., Inc., 1958.

79/ R. Pollitzer, op. cit.

(3) Role of Trapping in Control Programs. Trapping is not a logical measure for large-scale rodent control operations since the personnel required to maintain and service large numbers of traps would be great. Trapping is used in control programs primarily for surveillance--that is, to capture rodents periodically to examine them for fleas. Thus used, trapping does have a supplementary value in certain situations, but it is not a major control measure.

c. Fumigants

(1) Types of Fumigants. Carbon disulfide, carbon dioxide, carbon monoxide, chloropicrin, hydrocyanic acid, calcium cyanide, methyl bromide, phosphine, and sulfur dioxide have all been employed as fumigants at one time or another. Of these, hydrocyanic acid, calcium cyanide, and phosphine are employed in current practice. It cannot be stated too strongly that the use of fumigants should be restricted to trained, experienced pest-control operators since all of these agents are highly toxic to man in the concentrations required to kill rats.

(2) Comparative Effectiveness. Since all fumigants applied at the proper concentration are effective in killing rodents, this section presents other characteristics for or against their use.

Carbon disulfide is flammable, has an undesirable odor, and is too dangerous for use in enclosed areas.

Carbon dioxide is rarely used since extremely high concentrations are required for lethal effect.

Carbon monoxide does destroy the rodents, but it does not, in general, destroy the rat flea. In order to kill rat fleas, a 45-minute exposure at 122° F. is required.[80/] (Auto exhaust is a readily available source of carbon monoxide.)

Chloropicrin is irritating to the eyes, slower acting than hydrogen cyanide, toxic to living plants and seeds, and its odor persists for many days following application. It is, however, nonflammable and noninjurious to fabrics.

Hydrogen cyanide is extremely hazardous and has a characteristic odor, but it is highly effective as a fumigant.

Methyl bromide, characterized by a delayed toxic action, is not often employed as a fumigant.

80/ Ibid.

Sulfur dioxide has a distinctive, irritating odor, tarnishes metal, and is damaging to cereal products. It is no longer favored as a fumigant.

Calcium cyanide, a solid in the form of dust, reacts with moisture to form hydrogen cyanide; this gas is commonly used as a fumigant.

Of these fumigants, hydrogen cyanide and calcium cyanide are preferred in current U. S. pest control practice. They are, however, much too dangerous to be used by inexperienced persons; only skilled pest-control operators should use these agents.

d. Ratproofing. Of all the rodent control measures considered in this analysis, ratproofing--in its several aspects--is the only effective, long-range control measure. Ratproofing reduces the capacity of the environment to support rodent populations.

(1) Structural Measures. Structural measures for ratproofing are directed to preventing the ingress of rodents into houses or other buildings. Several measures are available. For example, L-shaped curtain walls effectively prevent rodents from burrowing and entering under walls. Hardware cloth or similar materials effectively preclude ingress by such routes as vents, sewer pipes, and conduits. Sheet metal protects wooden sills and doors located at ground level against gnawing rodents. Rat guards prevent rodents from climbing up exterior pipes and drain spouts; these guards are similar to those used on mooring cables of ships. These relatively expensive structural measures are sound approaches for controlling commensal rodents.

(2) Harborage Elimination. Under postattack conditions harborage--that is, housing suitable for rodents--may be increased. Thus, a good job of community housekeeping will be needed to eliminate harborage. In the event of heavy structural damage, community housekeeping operations will necessarily be somewhat protracted.

(3) Protection of Food Supplies. "Food supplies" refers to foods in storage intended for human consumption. Both structural measures and harborage elimination are considered crucial to the protection of food supplies. A further control measure is storage of foods above ground to frustrate rodent attack. Rodenticides are also useful in the protection of food supplies. Another possible measure is

the use of chemical repellents as cordons.[81] (The fumigant, chloropicrin, is an effective repellent.) For example, a repellent might be distributed around a stack of grain bags to establish a barrier between the rodent and a potential source of food. An additional advantage of using chemical repellents is that they may force the rodent to eat bait containing an anticoagulant and thus increase the efficiency of a poisoning program.

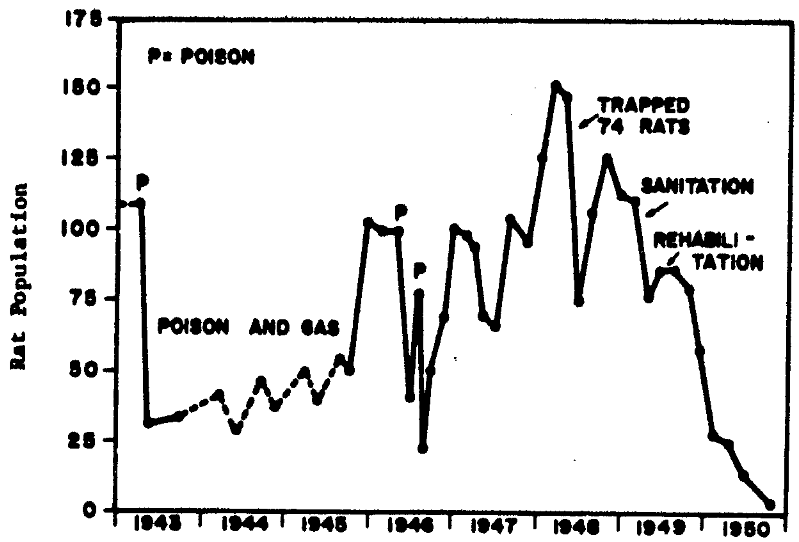
(4) Garbage and Refuse Disposal. Since improper storage and inadequate disposal of garbage and refuse provide a source of food for rodents, ratproofing depends in no small measure on early reinstatement of adequate collection and disposal of garbage and refuse.

4. Comparative Effectiveness of Rodent Control Measures. The measure discussed above that has maximum long-range effectiveness is ratproofing which reduces the capacity of the environment to support rodent populations. Poisoning with ingestants, fumigating, and trapping are less practical for continuing operations because they must be applied repeatedly as the rodent populations grow back toward capacity.

Figure 10 illustrates the relative effectiveness of rodent control measures. Note the pronounced and lasting effect of a rehabilitation program which included ratproofing measures such as structural measures, elimination of harborage, and disposal of garbage and refuse.

Ratproofing is accepted as the soundest approach during peacetime; however, following a thermonuclear attack, particularly one in which heavy structural damage occurs, rodenticides probably will be the most effective initial control measure. Anticoagulant rodenticides, for reasons cited above, appear preferable. When normal garbage and refuse disposal practices are reinstated, they will further counteract the development of large rodent populations. Other

81/ J. B. DeWitt and J. C. Besser, "Latest Report on U. S. Fish and Wildlife Service Research with Rodent Repellents," Pest Control, Vol. 26, No. 8 (1959), pp. 22-24, 59.



Source: P. E. Sartwell (ed.), Maxcy-Rosenau, Preventive Medicine and Public Health (9th ed.). New York: Appleton-Century-Crofts, Inc., 1956.

Fig. 10. History of Rat Population in Baltimore, 1943-1950.

ratproofing measures such as elimination of harborage and reconstruction of buildings, will be final postattack measures for the control of commensal rodent populations.

B. Control Measures for Wild Rodents

Wild rodents including the ground squirrel act as a reservoir for plague in Western U. S.[82/] Ingestant rodenticides, such as strychnine and arsenic, have been employed in the control of wild rodents. Fumigants which can be used with relative safety in the open air (including carbon disulfide, chloropicrin, and chlorine) have been used on wild rodent burrows. A common method of fumigating a wild rodent burrow is to place a cloth saturated with carbon disulfide in the burrow entrance; another method is to pipe auto exhaust into the burrow.

Generally, large-scale control of wild rodent populations is practically impossible.[83/] Only small-scale, highly localized control measures are practicable. The primary concern in the control of plague is surveillance of wild rodent populations.

82/ See Appendix B.

83/ R. Pollitzer, op. cit.

C. Miscellaneous Control Measures

Among rodent control measures rarely used are shooting or bludgeoning, flooding burrows, electrocution, catching rats on sticky surfaces, and using flame throwers.

While electrocution, the use of sticky substances, and flame throwers are impractical, eliminating rodents by shooting or bludgeoning them, or by flooding their burrows is not unreasonable for postattack conditions. For example, in one province of India a bounty was offered for rats.[84/] This served as an effective stimulus for a community program of rat bludgeoning.

While predators such as cats are commonly thought to be effective in reducing rodent populations, they actually are only twenty percent effective against the Norway rat.[85/] Dogs, however, particularly terriers, can deal effectively with the Norway rat; also, dogs are not nearly as susceptible as cats to plague. In general, not much reliance can be placed on predation as a means of controlling rodent populations.

Control measures for the rodent ectoparasite vectors of plague and murine typhus are discussed in the following section.

D. Rodent Ectoparasite Control Measures

Current plague and murine typhus control practice stresses primarily the control of rodent ectoparasites and secondarily the rodents themselves.[86/,87/] The ectoparasites of concern in this section are the rat fleas, in particular the Oriental rat flea, *Xenopsylla cheopis*.

1. Selective Application

All communities will not employ ectoparasite control measures as part of their postattack vector control activities. Rather, these measures will be instituted upon consideration of plague or murine typhus endemicity or upon the judgment of a threatened outbreak of these diseases. For example, communities in the San Francisco Bay area may employ ectoparasite control measures; Pittsburg, on the other hand, will probably not, since neither disease is endemic to that community.

84/ *Ibid*.

85/ *Ibid*.

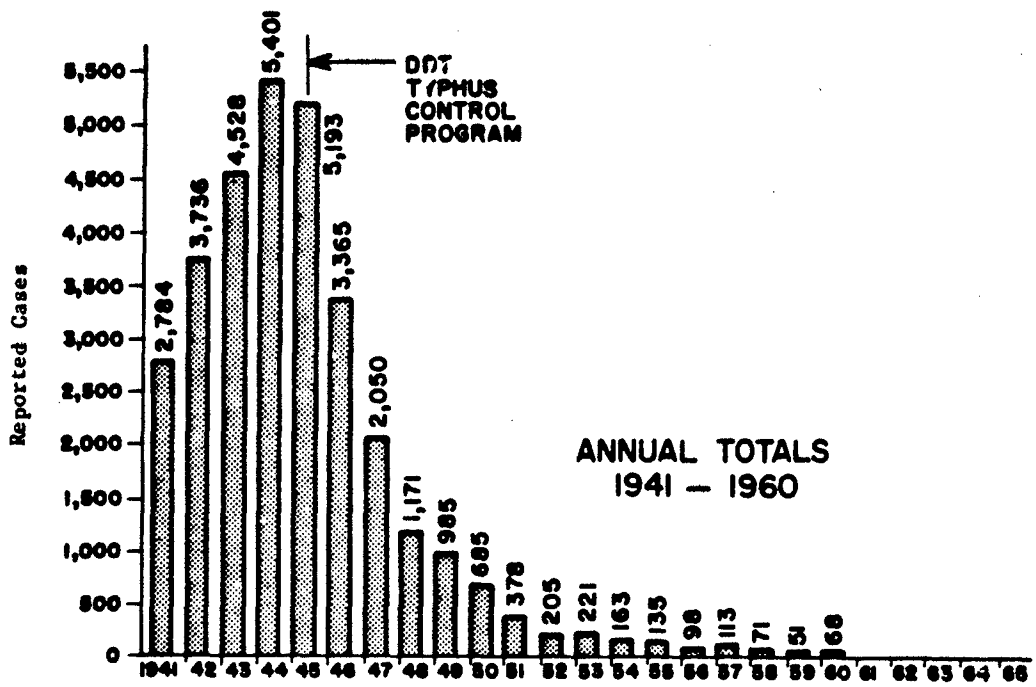
86/ J. E. Gordon and P. T. Knies, "Flea Versus Rat Control in Human Plague," *American Journal of Medical Science*, Vol. 213 (1947), pp. 362-376.

87/ Sartwell, *op. cit*.

2. Insecticides

a. Insecticide of Choice. Ten percent DDT dust is the insecticide of choice for the control of the Oriental rat flea.[88] Other compounds used for the treatment of premises or outdoor harborage include dieldrin, heptachlor, methoxychlor, benzene hexachoride (BHC), lindane, chlordane, aldrin, malathion, diazinon, dichlorvos, dipterex, and ronnel. The percentage concentrations for most of these agents are shown in Table XIII.

The effectiveness of DDT dusting in reducing the incidence of murine typhus is dramatically illustrated by Fig. 11.



Source: H. D. Pratt and J. S. Wiseman, Fleas of Public Health Importance and Their Control (Training Guide - Insect Control Series). Atlanta: U. S. Public Health Service, Communicable Disease Center, (n.d.).

Fig. 11. Reported Murine Typhus Cases in United States, 1941-1960.

88/ H. D. Pratt and J. S. Wiseman, Fleas of Public Health Importance and Their Control (Training Guide - Insect Control Series). Atlanta: USPHS, Communicable Disease Center (n.d.).

Table XIII

INSECTICIDES FOR RAT FLEA CONTROL

INSECTICIDES	Type of Treatment: Premise, Indoor — Oil Solutions or Emulsions**	Type of Treatment: Premise, Outdoor — Emulsions or Wettable Dust**	Type of Treatment: Large-Scale (Outdoor) — Dusts**
CHLORINATED HYDROCARBONS			
*DDT	5	5	5-10
Benzene Hexachloride	2-5	2-5	3-5
Lindane	0.5	1	—
Chlordane	2	2	2-5
Dieldrin	0.5	0.5	2
Aldrin	—	—	2.5
ORGANIC PHOSPHATE			
*Malathion	2	2	—
Diazinon	0.5	0.5	—
Dipterex	—	1	—
Ronnel	1	1	1

* Insecticide of Choice
** Numbers indicate percent of concentration of insecticide.

Source: H. D. Pratt and J. S. Wiseman, Fleas of Public Health Importance and Their Control (Training Guide - Insect Control Series). Atlanta: USPHS, Communicable Disease Center, (n.d.).

In practice beginning at the suspected focus of of infestation and working outward, DDT dust is applied to rat burrows, harborage, and runways. This strategem effectively limits the spread of infection among rodents, thus reducing the threat of infection in the human population. Approximately 4 pounds of dust are required for an average business establishment, 1 pound for urban residential premises, and 2 pounds for rural premises.

In endemic areas dust applications are advisable approximately every six months. A single dusting in the late spring is said to be sufficient in the northern part of the U. S. murine typhus belt.[89/]

b. Insecticide Resistance. DDT resistance in the Oriental rat flea has been reported from Ecuador and India.[90/] Such observations have not been made in the United States, however, DDT dust is today the insecticide of choice for the control of fleas transmitting plague and murine typhus.

3. Flea Repellents

Flea repellents may be applied directly to the ankles and trouser legs as needed or as a clothing impregnant. Repellents which may offer some relief to workers in heavily infested areas include dimethyl phthalate, benzyl benzoate, M-1960, and diethyl-toluamide. Diethyl-toluamide is distributed commercially in a number of preparations. A diethyl-toluamide concentration of at least 15 percent is required for maximum effectiveness.

4. Time Constraints for Application

If a quick-kill rodenticide is to be employed, DDT dusting must take place approximately three to five days prior.[91/] Otherwise, the rodenticide would kill the rat too soon and cause the flea to leave the rat. On the other hand, if an anticoagulant is to be used, the application of DDT may take place simultaneously since the anticoagulant requires three to four days to achieve its lethal effect.

E. Postattack Rodent Control Measures

For the control of those vectorborne diseases in man for which rodents are the hosts (plague and murine typhus), the main requirement is prevention of contact between rodents or rodent ectoparasites and man. In considering the potential methods for accomplishing this objective in the postattack period, the following considerations are basic:

89/ Ibid.

90/ Ibid.

91/ J. E. Gordon and P. T. Knies, op. cit.

1) Environment control (food and harborage reduction) is the only permanent means of control (see figure 9).

2) Rats seldom cross an open area as wide as an ordinary street (see section III.A).

3) A postattack buildup of the rat population will probably be a matter of a few months rather than days or a few weeks (see section III.A).

Therefore for the control of vectorborne diseases, it is suggested that emphasis be placed on environmental separation of people and rodents. Rodent poisoning and ectoparasite control would be required only in those relatively few cases where it was found absolutely necessary for people to occupy areas with either initially large rodent populations or large immigrant rodent populations.[92/] The actions indicated by this strategy are summarized in Table XIV. Note that these are actions for the early postattack period before essentially normal control measures could be resumed. The timing of resumption of normal operations would depend on the level of national damage as well as on the local situation.

Throughout the period of expedient action it will be of prime importance to inform the public of all known dangers from rodentborne disease. This information alone could be instrumental in keeping the human population from contact with rodent populations.

92/ Control of enteric diseases may require control of rodent populations not in direct contact with man. This might be required to prevent contamination of water or food.

Table XIV

SUMMARY OF EARLY POSTATTACK RODENT CONTROL MEASURES

Postattack Simulation	Effects on Rat Population	Major Actions: General	Major Actions: Specific
No direct effects, little or no fallout	ESSENTIALLY NONE. Reduced availability of commercial rodenticides may force curtailment of poisoning programs. Manpower and resource restrictions may curtail regular collection of garbage. However, scarcity of food may curtail production of garbage.	Inform population of dangers from rodentborne diseases.	Increase emphasis on sanitation and elimination of harborage. Private incineration of garbage may also be indicated.
No direct effects, moderate to heavy fallout	Some reduction of existing population by death from radiation, reduction of rate of population increase by genetic damage from radiation, some increase in population potential (unattended food stores may afford increased food and harborage for rats).		Eliminate rat runs and harborage and form "breaks"* during process of decontamination. Provide for ratproof disposal of spoiled food and protect food stores.
Light to moderate direct damage, little or no fallout	Probably little reduction of existing population by death from direct effects (fire, flying debris, etc.) Migration possibly caused by disturbed environment. Possibly great increase in population potential--debris affords harborage and damage may make food stores more accessible. No lasting genetic limitations on population growth.		Salvage food and provide for ratproof disposal of spoiled food. In clearing debris, form "breaks"* at roadways (clear preattack debris in process). Poisoning may be indicated by local conditions--likely necessary in Western cities.
Light to moderate direct damage, moderate to heavy fallout	Some reduction of existing population by death from radiation and direct effects, migration possibly caused by disturbed environment. Reduction in population potential by fallout radiation (genetic damage) versus increase in population potential by increased harborage and food availability.		Salvage food and provide ratproof disposal of any spoiled food in populated enclaves.** Clear "breaks"* during decontamination around enclaves and along roads. Consider ratproof demolition. Poisoning accompanied by ectoparasite control in enclaves probably indicated in Western states.
Heavy damage	Some initial population may survive (several rats) or migration may repopulate.		Isolate with "breaks" if rat population increases. Take precautions against infected rats during eventual recovery. (Consider rat population during demolition of remaining structures and clearing for new construction).

* "Break" = wide, clean surface such as a wide street to retard movement of rats.

** Assuming that urban human populations will initially be in shelter or decontaminated "enclaves" in the fallout-debris field.

VII. DELOUSING MEASURES

This section is concerned with the control of epidemic typhus by destroying lice and louse eggs (delousing) with chemical and physical agents.

A. Insecticides

1. Insecticide of Choice. The experience of World War II clearly indicates that DDT dust is the insecticide of choice in the treatment of persons infested with body lice. The effectiveness of DDT dust was demonstrated in Naples during the winter of 1943-1944 and in the prison camp at Belsen during the spring of 1945 where typhus epidemics were brought under control.[93/,94/] DDT dusting does not require the removal of clothing, a distinct advantage for mass application. While DDT is not an active ovicide, it has sufficient residual action to be effective against newly-hatched lice for several weeks.[95/] The step-by-step procedures employed in mass delousing using DDT dust are described elsewhere.[96/] A variation of DDT dusting is to impregnate clothing, particularly underclothing, with a DDT-bearing material. This method has been used successfully in highly infested areas.[97/]

Other insecticides which have been employed against body lice include: MYL powder; 1 percent lindane dust; NBIN concentrate; the vegetable insecticides, rotenone and sabadilla; and the organic phosphate compound, malathion.

2. Insecticide Resistance. Body lice resistant to 10 percent DDT dust were encountered during the Korean War. In the event of DDT resistance, 1 percent lindane dust can be used effectively.[98/] Lindane dust, however, requires a second application approximately seven to ten days following the first treatment. Organic phosphate compounds are also effective against body lice.[99/]

93/ F. L. Soper, et al., "Typhus Fever in Italy, 1943-1945, and Its Control With Louse Powder," American Journal of Hygiene, Vol. 45 (1947), pp. 305-334.

94/ W. A. Davis, "Typhus at Belsen: I. Control of the Typhus Epidemic," American Journal of Hygiene, Vol. 46, No. 1. (1947), pp. 66-83.

95/ H. D. Pratt and K. S. Littig, Lice of Public Health Importance and Their Control (Training Guide - Insect Control Series). Atlanta: USPHS, Communicable Disease Center, 1961.

96/ F. L. Soper, et al., op. cit.

97/ P. A. Buxton, The Louse. London: Edward Arnold and Co., 1946.

98/ H. D. Pratt and K. S. Littig, Lice..., op. cit.

99/ M. M. Cole and G. S. Burden, "Phosphorus Compounds as Ovicides and Adulticides Against Body Lice," Journal of Economic Entomology, Vol. 49, No. 6 (1956), pp. 747-750.

B. Heat Treatment of Infested Clothing

Since body lice lay their eggs in the folds of clothing, effective delousing is directed to the clothing itself; heat treatment of clothing affords a simple, effective control measure. Clothing may be deloused by boiling it in water for a short period of time. Table XV indicates that a temperature of 124.5° F. kills body lice in five minutes; other time-temperature relationships are also presented in Table V.

Table XV

TIME AND TEMPERATURE REQUIREMENTS FOR DELOUSING GARMENTS

Time Minutes	Temperature	
	°Centigrade	°Fahrenheit
5	51.5	124.5
30	49.5	121.1
60	46 or 47	115 to 116.6

Source: P. A. Buxton, The Louse. London: Edward Arnold and Co., 1946.

C. Cold Treatment of Infested Clothing

Just as high temperatures kill body lice, so do low temperatures. The low temperature limits for survival of louse eggs are shown in the time-temperature curve of Fig. 12; the lethal effect of low temperature on adult lice is shown in the curve of Fig. 13. Thus, exposure of infested clothing to low temperatures for an appropriate period of time constitutes a simple, effective delousing method.

D. Storage of Infested Clothing

Another delousing measure is to store the clothing for one month to assure the death of both mature and developing lice.[100]

E. Choice of Delousing Measure

Given the proper circumstances, both physical and chemical agents are effective as delousing measures. The use of physical agents requires that a change of clothing be available. For mass delousing, DDT dust is clearly the agent of choice. Studies have failed to demonstrate a significant DDT resistance problem in the lice indigenous to the United States.[101]

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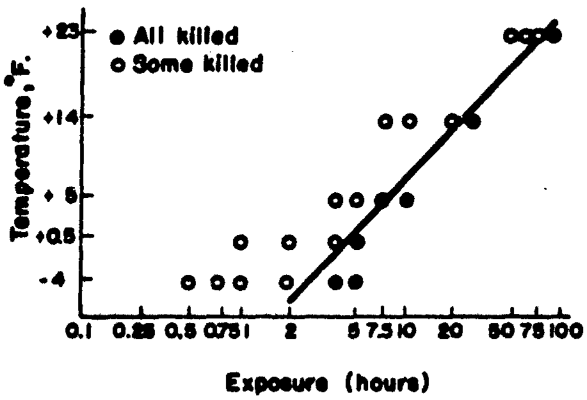
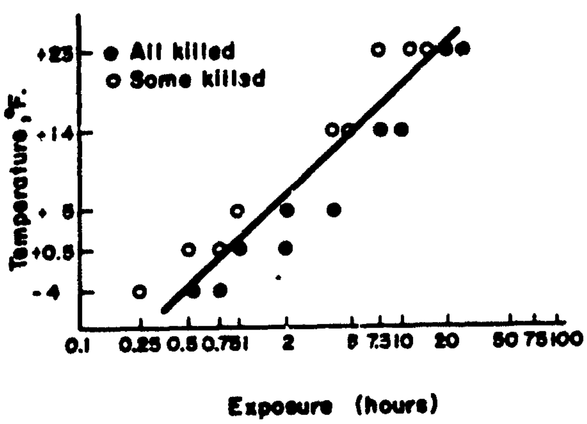
[100] H. D. Pratt and K. S. Littig, Lice. . ., op. cit.

[101] Ibid.



Source: P. A. Buxton. The Louse. London: Edward Arnold and Co., 1946.

Fig. 12. Resistance of Body Louse Eggs to Low Temperatures.



Source: P. A. Buxton, The Louse. London: Edward Arnold and Co., 1946.

Fig. 13. Resistance of Body Louse to Low Temperatures.

VIII. MOSQUITO CONTROL

The most important mosquito vectors for the several forms of encephalitis are *Culex tarsalis* as the main vector of Western and St. Louis encephalitis in the west, *Culex pipiens-quinquefasciatus* complex as the main vectors of St. Louis encephalitis from Texas to the Ohio Valley, and *Culex nigripalpus* as the vector of St. Louis encephalitis in Florida.[102/]

C. tarsalis is mainly a rural mosquito but the larvae develop in a wide variety of aquatic situations. Although often associated with temporary or semipermanent irrigation water, they also breed extensively in artificial containers and in effluent from cesspools and other waters containing large amounts of organic matter. *C. pipiens-quinquefasciatus* (northern and southern house mosquitoes) are primarily urban species. They breed prolifically in rain barrels, tanks, tin cans, storm-sewer catch basins or poorly drained gutters, as well as in polluted ground pools, drains, etc. Heavy production of house mosquitoes is often associated with unsanitary conditions. *C. nigripalpus* is common to flooded fields, ditches, and grassy pools.[103/]

Adult *Culex* mosquitoes are nocturnal (night-biters), resting in shaded spots in the daytime.

Dispersion studies have shown that *C. tarsalis* will fly at least 10 miles, although the majority of individuals probably remain within one mile of their breeding sites. *C. pipiens-quinquefasciatus* species do not migrate far except when large numbers are being produced. Several generations are produced during the year with females laying several hundred eggs in rafts on the water surface. Larvae are usually suspended in the surface film although feeding on organic matter (algae, algalcysts, flagellates, etc.) may occur throughout the medium. One variety was observed to feed approximately 12 percent of the time at the surface, 15 percent on the bottom, and the remainder at intermediate levels, although in water 56 cm. deep very few larvae went to the bottom to feed.[104/]

102/ H. D. Pratt, R. C. Barnes, and K. S. Littig, *Mosquitoes of Public Health Importance and Their Control*, Communicable Disease Center, Public Health Service, U. S. Department of Health, Education and Welfare, Atlanta, Georgia, (Developmental).

103/ *Ibid.*

104/ W. R. Horsfall, *op. cit.*

"The only limitation put on numbers of individuals that a summer season might bring would be the availability of larval sites. As a consequence of variation in sites, one may calculate from Eckstein's data that populations might vary as much as 400-fold between seasons for any one locality."[105]

Control measures are directed against both larvae and adults. Larval control includes the reduction of available larval sites and thus would be most important in a postattack period, as has been found following natural disasters (e.g. floods). Burst water lines, blocked drainage channels, uncollected containers of garbage, decontaminated water, etc., might produce similar conditions of standing contaminated water in a postattack period.

A. Larval Control

A Public Health Service publication[106] contains an excellent summary of control methods, and only salient features will be abstracted for this report. The elimination of larval sites is accomplished by sanitation methods well known to public health personnel. These include sanitary disposal of refuse, drainage of standing water, and control of sewage effluent. Sanitation will be a major postattack concern in combating enteric diseases.[107] Mosquito control may be a secondary benefit from major sanitation efforts. Mosquito control benefits should be considered in planning sanitation operations, although more pressing threats of enteric infection will require first consideration.

Mosquito larviciding is the practice of killing mosquito larvae with stomach poisons or contact poisons. Larvicidal control is currently of primary importance in areas where immediate control of pest or disease-carrying mosquitoes is necessary, particularly in cases of extensive flooding following natural disasters such as hurricanes or prolonged rainy seasons. Temporary larvicides include the following:

1) Petroleum oils,
2) Pyrethrum I and II (extracts from the seeds of the chrysanthemum plant, largely used in gardens, ponds, etc.),

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105/ *Ibid.*, p. 564.
106/ Pratt, *et al.*, *op. cit.*
107/ Titchen, *op. cit.*

3) Paris Green (use was largely discontinued with the advent of DDT in the 1940's),

4) Chlorinated hydrocarbons (DDT, benzene hexachloride, lindane, chlordane, heptachlor, and dieldrin are the most widely used), and

5) Organic phosphorus insecticides (Abate malathion, parathion, and methyl parathion are among the most widely used in mosquito control programs).

Residual larvicides have been used for larval control over extended time periods. Results are summarized in Table XVI.

Table XVI.—*Mosquito control with residual larvicides in various parts of U.S.*

Insecticide	Application rate technical grade insecticide equivalent in pounds per acre	Weeks of satisfactory control	Species of mosquito, location of control study
BHC emulsion	1 (gamma isomer).	5–8	Anopheline and culicine larvae in land-locked ponds, Savannah, Ga.
*DDT emulsion	3	12–24	
*Dieldrin emulsion	1	Season	
*Dieldrin emulsion	3	14	*Culex tarsalis, Culex peus.*
Heptachlor emulsion	3	8	*Culex pipiens, Culiseta incidens* in log ponds in Oregon.
*DDT emulsion or granules	10	8 and 7	
Malathion emulsion	3	5	
Heptachlor emulsion	5	10	
Heptachlor granules	5	13	
*Dieldrin emulsion or granules	1	Season	*Aedes vexans, Aedes dorsalis, Culex tarsalis* in alfalfa fields and pastures in Montana.
*Dieldrin emulsion	1	Season	*Psorophora confinnis* in rice fields in Mississippi.
Dieldrin emulsion	0.25	Season	Various species in ditches, alfalfa fields and pastures in Montana.
DDT granules	1.5	Season	
Heptachlor granules	0.75	12	

*Totally destructive to fish and wildlife.

Source: H. D. Pratt, R. C. Barnes and K. S. Littig, Mosquitoes of Public Health Importance and Their Control. Communicable Disease Center, U. S. Department of Health, Education and Welfare, Public Health Service, Atlanta, Georgia.

B. Control of Adult Mosquitoes

There are essentially two strategies for controlling adult mosquitoes. The first strategy is to control the environment immediately surrounding a person to retard entry of adult mosquitoes. This strategy includes the well-known methods of screening, use of bed nets, mosquito-proof clothing, repellents, and the familiar aerosol spray insecticide. These methods are not suitable for community application on an emergency basis. The method of applying

residual sprays on building surfaces to leave a film which will kill insects for weeks or months may also be classified with this strategy (although it also has uses in areawide control programs).

The second strategy may be characterized as areawide control of adult mosquitoes. Insecticides employed for this purpose include DDT, fenthion, naled and malathion. Although there has been a recent increase in the use of dusts--and mists are also used--fogging[108/] is the technique of choice for controlling adult mosquitoes in the day-to-day peacetime operations. Conventional spraying vehicles move at an average speed of five miles per hour producing effective control in a 400-foot-wide swath.

"Space spraying is the chief activity of many organized mosquito abatement districts and is (wrongly) the only method used by an even larger number of communities which attempt to reduce mosquito annoyance without the aid of entomologist, engineer, or trained mosquito control specialist."[109/]

Aerial application of insecticides has been practiced for many years. Most significant for postattack operations, however, is the recent development of the "ultra low volume" (ULV) technique of aerial application in which a volume of one half gallon or less of undistributed concentrate is applied per acre. The use of such low volumes allows an airplane to treat a much wider area per trip, and thus conserves time and fuel. In tests the plane flew at 150 miles per hour and produced effective swath widths of 300 to 500 feet from an altitude of 100 to 150 feet. The technique also shows promise as a larvicidal measure.[110/]

The U. S. Air Force used C-123 aircraft in ULV treatments for curbing the outbreak of St. Louis encephalitis in Texas in 1966. At Dallas approximately 500,000 acres and at Corpus Christi approximately 100,000 acres received a single treatment with 3 ounces of malathion per acre. The incidence of encephalitis cases dropped to almost zero within 2 weeks after the initiation of spraying. Detailed observations indicated that these treatments provided 90-95% reductions in the adult *C. quinquefasciatus* population and 70-75% reduction in larval infestation.

C. Resistance of Mosquitoes

It is well known that insects may develop resistance to specific insecticides.

108/ Fogging produces much smaller droplets than misting and thus the material does not settle as quickly, giving effective treatment over a wider area.

109/ Pratt, *et al.*, *op. cit.*

110/ Communicable Disease Center, "1967 National Communicable Disease Center Report on Public Health Pesticides," *Pest Control*, March 1967, pp. 13-40.

In general, resistance to insecticides is defined as the ability of many individuals in a population to withstand a poison which was generally lethal to earlier populations. In the United States physiological resistance (the ability through physiological processes to withstand a poison after it has been encountered) is most important. The ability to avoid lethal contact with a toxicant through behavioral changes (behavioristic resistance) has not appeared to be important in the United States. Resistance is probably a genetic phenomenon not created by the insecticide but merely revealed by it.[111/] Table XVII summarizes the known resistance of mosquitoes to insecticides in the United States. Although many of the species shown in Table XVII are not of concern in the spread of encephalitis, they illustrate the extent of the resistance problem.

Table XVII

SPECIES OF U. S. MOSQUITOES RESISTANT TO INSECTICIDES

Species	Area	Insecticide
Aedes aegypti	Trinidad, Florida	DDT, dieldrin.
dorsalis	California	DDT.
nigromaculis	do	DDT, toxaphene, lindane, aldrin, heptachlor, malathion, parathion.
sollicitans	Florida	DDT, dieldrin.
taeniorhynchus	Florida, Georgia	Do.
Culex pipiens	Massachusetts	DDT.
quinquefasciatus	Puerto Rico	DDT, malathion, dieldrin.
tarsalis	California, Oregon	DDT, malathion.
Psorophora confinnis	Mississippi	Dieldrin.
discolor	do	Do.
Anopheles quadrimaculatus	Georgia, Mississippi	DDT, dieldrin.

Source: H. D. Pratt, R. C. Barnes, and K. S. Kittig, Mosquitoes of Public Health Importance and Their Control. Communicable Disease Center, U. S. Department of Health, Education, and Welfare, Public Health Service, Atlanta, Georgia.

The mosquitoes which produce multiple generations per year (and consequently have more opportunity for adaptation through natural selection to withstand adverse environments) have shown most resistance to insecticides. These species include important encephalitis vectors. Although behavioristic resistance has not appeared in the United States, it remains a possibility.

One may speculate that development of behavioristic resistance to radiation effects of fallout may be important to these species when they are exposed to continuous fallout fields.

111/ Pratt, *et al.*, *op. cit.*

Those individuals most prone to feed in the surface film and rest in protected places would be least likely to come into contact with fallout material and the resulting beta radiation. Insects are generally resistant to gamma radiation and a population avoiding direct contact with fallout material might be little affected by fallout.

D. Postattack Mosquito Control Operations

Postattack mosquito control operations will be conducted, at least in the early postattack period, as emergency operations. The comparatively low level of the threat from mosquitoborne encephalitis established in section V and the success which has been achieved by aerial spraying after encephalitis is detected, indicate that reliance on control of epidemics rather than on prevention should characterize the early postattack mosquito control programs. Because of different recovery rates for areas suffering different levels of damage (and for the nation after different levels of attack), definite time schedules for resumption of essentially normal mosquito control operations cannot be rigidly specified.

As indicated in the previous section, aerial spraying seems to be the method of choice for preattack control of encephalitis epidemics. Two additional factors support aerial spraying as the method of choice in the postattack period:

1) The equipment can be brought quickly to bear on the area suffering an encephalitis epidemic, even with the airplanes located a long distance from the trouble spot.
2) In the very likely case that fallout would restrict ground operations, the greater speed and altitude of the aircraft could reduce the radiation dose to the crew sufficiently to allow aerial operations.

In conventional spraying from trucks operating at 5 miles per hour, with a swath 400 feet wide, approximately 15 miles must be traveled to cover a square mile (5280/400 = 13.2 swaths required; allowing for some overlap yields approximately 15 swaths, ignoring turnaround). Thus approximately 3 hours are required. If the fallout field produces a clear field dose of D_o roentgens and the track crew has a protection factor of 1.5, $(3/1.5)\ D_o = 2D_o$ roentgens are received per square mile sprayed. In an aerial spraying operation at 150 miles per hour at 100 feet altitude, even if 20 swaths are required (greater overlap may be required to assure coverage), only 0.133 hours are required to cover a square mile. With an altitude reduction of 0.375[112]

[112] Shelter Design and Analysis, Volume 1, Fallout Protection. TR-20-(Vol. 1). Washington: Office of Civil Defense, May 1964, pp. 4-12.

and not considering any structural shielding or ground roughness factor, the airplane crew would receive 0.05 D_e roentgens per square mile sprayed (a factor of 40 less than the ground crew).

IX. HAZARDS TO VECTOR CONTROL OPERATORS

A. Toxicity Versus Hazard

Toxicity refers to the physiologic effect resulting from intimate contact of a given organism with a toxic agent. In contrast, hazard refers not only to the toxicity but also to the likelihood that the agent will come in contact with the organism--in this instance, man.

B. Threshold Limit Values

Threshold limit values refer to a healthy worker employed eight hours a day for five days a week, incorporate both toxicity and hazard considerations, and are stated as air concentrations. These values indicate air concentrations at or above which the most sensitive individuals may show symptoms of intoxication.

Table XVIII gives the threshold limit values for 1965 as published by the American Conference of Governmental Industrial Hygienists,[113/] for both ingestant and fumigant rodenticides. Table XIX gives the threshold limit values for a number of the insecticides used in vector control operations.

In Table XVIII note the extreme hazard in handling sodium fluoroacetate (a quick-kill agent) in contrast to handling warfarin and pival, representative anticoagulants. Skin exposure is a hazard in handling many pesticides listed in Tables XVIII and XIX. Gloves, respirators, and other protective gear are indicated for handling bulk quantities of these agents.

113/ Threshold Limit Values for 1965. Cincinnati: American Conference of Governmental Industrial Hygienists, 1965.

Table XVIII

THRESHOLD LIMIT VALUES FOR RODENTICIDES

Rodenticide	Air Concentration: p.p.m. by volume at 25°C and 760 mm. Hg	Air Concentration: Approximate mg/m^3
Ingestants		
ANTU	-----	0.3
Arsenic and Compounds (as As)	-----	0.5
Pival	-----	0.1
Sodium fluoroacetate (1080)*	-----	0.05
Warfarin	-----	0.1
Fumigants		
Carbon dioxide	5,000	9,000
Carbon disulfide*	20	60
Carbon monoxide	50**	55**
Chloropicrin	0.1	0.7
Hydrogen cyanide*	10	11
Sulfur dioxide	5	13

* Skin exposure

** Tentative value

Source: Threshold Limit Values for 1965. Cincinnati: American Conference of Governmental Industrial Hygienists, 1965.

Table XIX

THRESHOLD LIMIT VALUES FOR INSECTICIDES

Insecticide	Air Concentration Approximate mg/m^3
Aldrin*	0.25
Chlordane*	0.5
DDT*	1.0
Dieldrin*	0.25
Heptachlor*	0.5
Lindane*	0.5
Malathion*	15
Methoxychlor	15
Pyrethrum	5
Rotenone	5
Toxaphene*	0.5

* Skin exposure

Source: Threshold Limit Values for 1965. Cincinnati: American Conference of Governmental Industrial Hygienists, 1965.

X. PREPARATION FOR POSTATTACK VECTOR CONTROL OPERATIONS

From the analyses described above, DDT and anticoagulant poisons emerge as the critical chemicals for postattack vector control operations. The objectives of this section are: to evaluate the need for stockpiling and preattack deployment of these chemicals, to estimate their probable postattack availability, and to identify the costs associated with insuring their availability and proper utilization.

A. Stockpiling

Stockpiling of DDT and DDT substitutes is evaluated for both in-shelter and out-of-shelter.

1. In-Shelter Stockpiling. The threat of epidemic typhus is greatest during the early post-shelter period due to crowding conditions. Although the magnitude and timing of the postattack epidemic typhus threat do not warrant stocking NFSS shelters with DDT at this time, crisis-oriented plans appear advisable.

Two ounces of DDT dust are sufficient for delousing an individual.114/ The DDT dust is available in 2-ounce sifter cans as well as 5- and 25-pound bulk containers. An adequate in-shelter stockpile for 200 spaces would consist of 50 pounds of 10 percent DDT dust, two hand dusters, and instructions for their use. This stockpile allows for spillage and limited alternate uses such as control of rodent ectoparasites. An estimate of $4.75 per hundredweight for 10 percent DDT powder in 50-pound cans was obtained from a local price quote. With one 50-pound can per 200 people the cost of insecticide alone would be $\$8.33 \times 10^5$ for the 70 million people in the region at risk to typhus. If none of these 70 million people were killed by other effects, between 1.1×10^4 and 3.0×10^5 lives might be lost to epidemic typhus if no precautions were taken (see Table IX, p. 42). Even allowing for the use of expedient applicators (no cost), this yields cost-effectiveness ratios of 75.70 and 2.78 dollars per life saved, with the large cost being more likely. A recent study115/ has shown that for the CIVLOG attack in Rhode Island, ventilation of basements would cost, on the average, $2.50 per life saved and special purpose fallout shelters would cost, on the average, $70 per life saved. Thus current stocking of DDT in shelters would probably not be a cost-effective addition to the NFSS system.

114/ H. D. Pratt and K. S. Littig, Lice . . ., op. cit.

115/ P. S. McMullan, J. C. Wright, H. S. Anderson, S. Trustman, Budget Allocation for Shelter Systems, R-OU-230-1. Research Triangle Institute, Research Triangle Park, North Carolina, June 1967.

2. Out-of-Shelter Stockpiling.

a. Normal Industrial Inventories. End-of-season (as of September 30) inventories of DDT and DDT substitutes (BHC and Aldrin group) for 1955 through 1964 are presented in Table XX. The approximate mean DDT inventory during this period was 31 million pounds; the maximum, approximately 45 million pounds. The range of values in this table reflects a general upward trend in the use of these chemicals. Normal industrial inventories appear to constitute an adequate stockpile for the postattack control of rodent ectoparasites, nationally.

The U. S. Government carries 10 percent DDT in pyrophyllite and 1 percent lindane in pyrophyllite as stock items.116/

Table XX

U. S. INDUSTRIAL INVENTORIES OF DDT AND DDT SUBSTITUTES AT END-OF-SEASON, 1955-64

Insecticide	Inventory - Million lb.		
	Minimum	Mean	Maximum
DDT	22.8	30.8	44.8
BHC, including Lindane	3.9	21.3	29.4
Aldrin Group*	16.4	36.7	46.6

* Includes aldrin, chlordane, dieldrin, heptachlor, and toxaphene

Data Source: Agricultural Stabilization and Conservation Service, The Pesticide Situation (various annuals). Washington, D. C.: U. S. Department of Agriculture.

b. Normal Consumption of DDT and DDT Substitutes. Calculated monthly consumptions of these chemicals in millions of pounds per month are shown in Table XXI.

c. Supplies on Hand. The estimated months' supply of DDT available for postattack vector control operations is shown in Table XXII.

116/ Ibid.

Table XXI

MONTHLY DOMESTIC CONSUMPTION OF DDT AND DDT SUBSTITUTES, 1952-1964*

Insecticide	Consumption - Million lb./mo.		
	Minimum	Mean	Maximum
DDT	3.8	5.4	6.6
BHC	0.1	0.5	0.8
Aldrin Group**	2.8	5.5	6.9

* Based on disappearance at producers' level.

** Includes aldrin, chlordane, dieldrin, heptachlor, and toxaphene.

Data Source: Agricultural Stabilization and Conservation Service, The Pesticide Situation (various annuals). Washington, D. C.: U. S. Department of Agriculture.

Table XXII

ESTIMATED MONTHS' SUPPLY OF DDT AVAILABLE FOR POSTATTACK VECTOR CONTROL OPERATIONS*

Inventory Level	Consumption Level		
	Minimum	Mean	Maximum
Minimum	6	4.2	3.5
Mean	8.2	5.7	4.7
Maximum	11.8	8.3	6.8

* Calculated from data presented in Tables XX and XXI.

The figures in Table XXII, based on the data presented in Tables XX and XXI, indicate a supply of DDT adequate for 3.5 to nearly 12 months' operations. These estimates, presumed conservative since they reflect widespread non-essential agricultural use of DDT, are based on inventories at the producer level and do not include inventories located at other levels in the distribution chain. (It is assumed that DDT used in nonessential agriculture could be diverted into vector control operations.)

Similar data for the anticoagulant rodenticides are not readily available, but it is believed that inventories adequate for postattack rodent control operations exist in the distribution chain.

B. Deployment of Pesticides

1. Producers of Agricultural Pesticides. In 1963, 340 establishments were involved in the production of agricultural pesticides (SIC 2879).[117] A specialization ratio of 0.87 (value of primary product shipments/value of primary plus secondary product shipments) and a coverage ratio of 0.69 (value of primary product shipments/value of primary product shipments of all industries) characterized this industrial classification in 1963.[118] The location of these establishments by state is shown in Fig. 14. The geographical distribution of producers appears to result in an adequate preattack deployment of pesticides. A list of locations of pesticide producers and formulators which was derived from another source is given in Appendix D.

2. Preattack Crisis Deployment. In a crisis situation the deployment of DDT stock to shelters to be used in preventing louse infestation would be useful. If the insecticide is available, all persons at risk to epidemic typhus should be deloused.

3. Postattack Deployment. The time constraints for the application of rodent and rodent ectoparasite control measures appear to be on the order of several months postattack. Thus, several months are available for the deployment of pesticidal chemicals to areas requiring them.

C. Vaccines and Chemotherapy

Although vaccines for plague, epidemic typhus, and murine typhus are available, their use has been largely restricted to medical personnel (or other workers outside of the main population). Vaccines have not been found to be an efficient means for controlling epidemics of vectorborne diseases. Control of the vectors or host populations has proven more efficient than any immunization program in controlling epidemics of vectorborne diseases.[119]

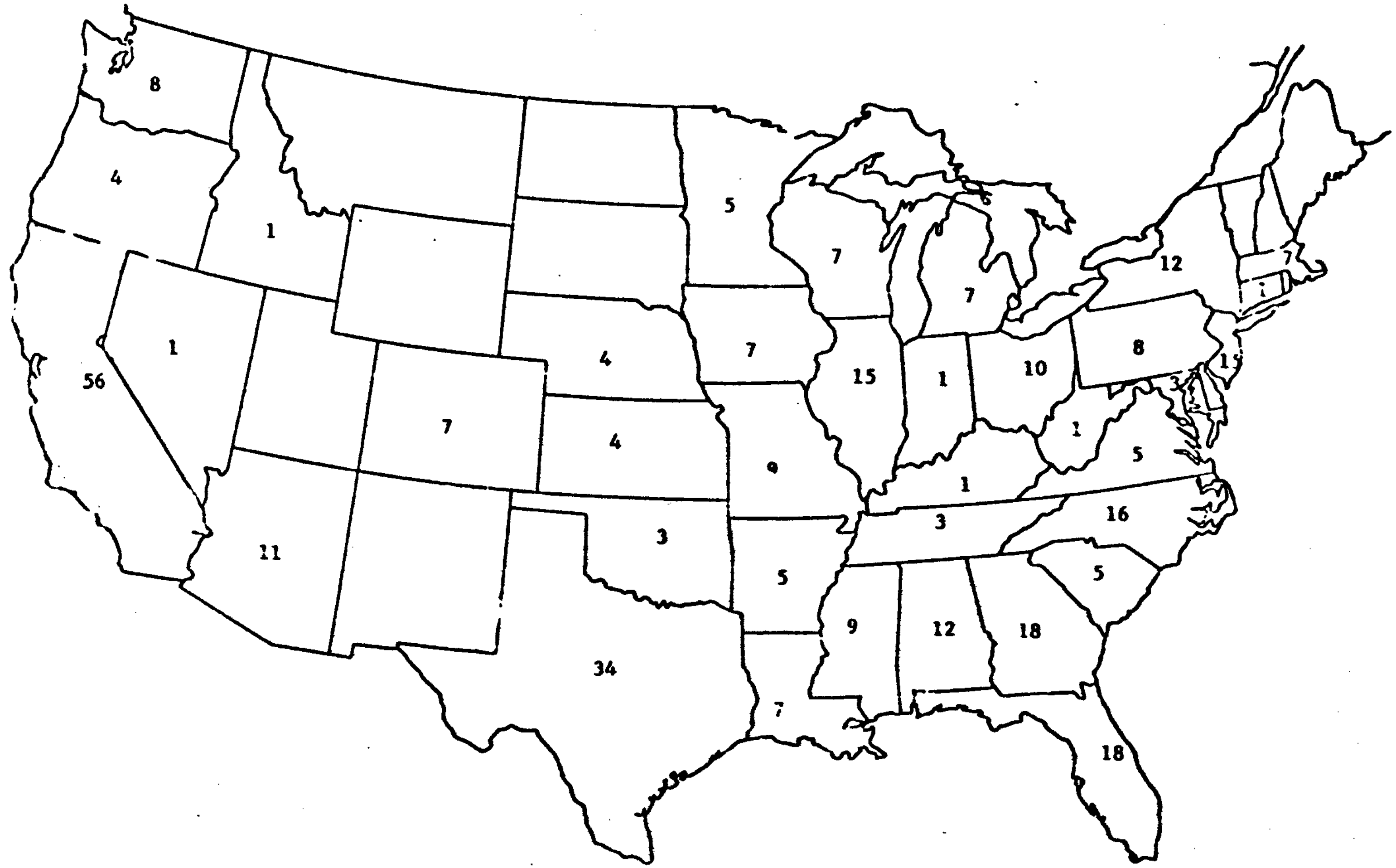
Chemotherapeutic agents are known which are efficacious in treating plague (streptomycin and sulfonamides), and murine and epidemic typhus (chloramphenicol and drugs of the tetracycline series).[120] However, the full effectiveness of stockpiling these drugs cannot be determined by considering only their use against these diseases. Their use against vectorborne diseases should be considered in addition to their use against other diseases when considering the value of such stockpiles.

117/ U. S. Bureau of the Census, Census of Manufacturers, 1963 INDUSTRY STATISTICS: Agricultural Chemicals, MC 63(2)-28F. Washington, D. C.: U. S. Government Printing Office, 1966.

118/ Ibid.

119/ Top, op. cit.; Kartman and Prince, op. cit.

120/ Maxcy, op. cit.; and Kartman and Prince, op. cit.



Data Source: U. S. Bureau of the Census, Census of Manufacturers, 1963 INDUSTRY STATISTICS: Agricultural Chemicals, MC 63(2)-28F, Washington, D. C.: U. S. Government Printing Office, 1966.

Fig. 14. Number and Location of Establishments Producing Agricultural Pesticides and Other Agricultural Chemicals (SIC 2879) in 1963.

The vaccine for rabies is of course highly specific, is given in a series of shots after suspected exposure, and does not have a long shelf life.[121/] Since the postattack rabies threat is at worst marginal, efforts to develop a stockpile of vaccine are not warranted.

Vaccines are not available for the mosquitoborne encephalitides and treatment is on a symptomatic basis.[122/] Thus vector control is the only method of prevention and control.

D. Rabies Control

The control of rabies depends mainly on preventing association between people and rabid animals. Informing the public of the danger of rabies when it exists will be the most important single factor in preventing human cases. If the cat and dog population were to become infested with rabies in the first year postattack, the action indicated would be to kill as many as possible. The availability of a stock of privately owned guns and ammunition sufficient for this purpose appears obvious.

E. Identification of Preparedness Cost (Precrisis)

A community-wide inventory is required in order to estimate the availability of pesticidal chemicals and associated equipment for postattack operations. This inventory would identify the types and quantities of pesticides present in the community and should be updated annually. This seems a logical activity for the local civil defense director with cooperation from the local health agency.

Training selected individuals, particularly health personnel, to use chemicals and other resources for the control of vectors is essential for postattack operations. Short courses, both classroom and correspondence, could be used to meet this need. Medical self-help training could prepare a segment of the general public.

Since these costs are only revisions to plans during the normal periodic updating, or actions by personnel already employed, monetary costs cannot be fully estimated. The monetary costs depend upon which tradeoffs can be made.

F. Estimated Effectiveness

Without mathematical models with well-estimated parameters and knowledge of how each action would affect each parameter, no precise measure of effectiveness is possible. Judgment estimates must be relied upon in the present situation. Since plague and epidemic typhus are the diseases estimated to be of major importance, the estimates of effectiveness of their control are also of major importance.

121/ Top, *op. cit.*

122/ *Ibid.*

In Titchen's analysis[123] an epidemiologist estimated that vector control alone would reduce both the average and maximum sizes of plague and typhus epidemics by approximately 90 percent. The epidemiological similarity between ratborne plague and murine typhus would indicate that 90 percent would also be estimated for murine typhus. The dissemination of information and maintenance of quarantines would further enhance this effectiveness.

Recent epidemics of encephalitis which were controlled with aerial spraying (after several cases were reported) have been less than 10 percent the size of the largest recorded epidemics before mosquito control. Thus, an effectiveness estimate of 90 percent seems reasonable for control of mosquitoborne encephalitis.

Strict animal control coupled with timely information to the public might be more or less than 90 percent effective in combatting rabies. However, 90 percent seems to be a reasonable estimate for the overall effectiveness of these countermeasures also.

The recommended countermeasures prevent cases, not just deaths. With an overall effectiveness of 90 percent, the best estimate of the vectorborne disease toll would thus be that 0.2 percent of the survivors would contract a vectorborne disease and 0.075 percent of the survivors would die from a vectorborne disease. From a surviving population of 100 million, 675,000 lives would be saved and 1.8 million disease cases would be prevented by the recommended actions.

[123] Titchen, op. cit.

XI. SUMMARY AND RECOMMENDATIONS

The main results of the threat analysis are presented in Table IX, page 42. On all accounts, plague presents the major national threat among the set of vectorborne diseases. If the Russian and Irish epidemics are taken as "best" estimates, epidemic typhus would rank as the second most important vectorborne disease threat. If, on the other hand, Titchen's estimates are weighted more heavily, epidemic typhus is of the same order of importance as encephalitis, murine typhus, and rabies. On the basis of death, murine typhus is of least importance; on the basis of cases, rabies is of least importance among the five diseases. It is again emphasized that rabies was included in this study of vectorborne diseases only because of its inclusion in previous analyses and because a comparison was desired.

In the comparisons of total <u>regional</u> risks the most severe estimate indicates approximately 4.00 percent of the population would have a vectorborne disease and 1.35 percent of the population would die from one of the five diseases during the first year postattack. The least severe estimates indicate the cases and fatalities are approximately 0.34 and 0.16 percent respectively. From these data a "best" estimate might be given as 2.00 percent cases and 0.75 percent fatalities due to all five diseases. Plague might account for one-half the cases and two-thirds of the deaths from vectorborne diseases. Epidemic typhus and mosquitoborne encephalitis would follow in that order of importance while murine typhus would rank fourth on the basis of cases and rabies would rank fourth on the basis of deaths.

The "best" estimate indicates that vectorborne diseases are a potential postattack health problem (0.75 percent of 100 million survivors of the weapon effects is 750,000 potential deaths). However, in comparison with the enteric disease threat estimated in previous studies, the vectorborne disease threat is an order of magnitude less than the postattack threat from the combination of enteric and man-to-man diseases.

Comparison of the risks from plague and epidemic typhus calculated for regional risk under the assumptions of this analysis and the corresponding risks calculated for uniform risk across the nation indicate the importance of plans to control population movements and disseminate information if epidemics occur.

Prevention of plague and murine typhus epidemics in the human population requires that man be kept from contact with flea infested rodent populations in regions where plague or murine typhus is endemic in the rodent populations. Environmental control is the only lasting means of rodent control. Thus elimination of rodent harborage and food in the vicinity of man is recommended whenever practicable. In situations where environmental control is not practicable or where initially large rodent populations

exist, the control method indicated is the simultaneous use of anticoagulant rodenticides and DDT (or a substitute insecticide to control the rodent fleas). The time constraints for the application of rodent and rodent-ectoparasite control measures appear to be on the order of several months postattack. Thus, several months are available for the deployment of pesticidal chemicals to areas requiring them.

Prevention of epidemics of louseborne (epidemic) typhus requires the control of human lice if an initial source of epidemic typhus is present. A case of Brill-Zinsser disease may be the initial focus. Dusting of the population with 10 percent DDT powder will control lice if ordinary sanitation practices become impracticable. Because of the time required for a buildup of the louse population and the incubation period of typhus in man, a precrisis, in-shelter stockpile of DDT is not a cost-effective addition to the NFSS shelter program. It might be a worthwhile addition to a special purpose shelter program in the urban northeast section of the country. Crisis period deployment of DDT is advisable as time permits.

The control of mosquitoborne encephalitis should be handled on a basis similar to current practice. That is, if an epidemic begins and the threat is deemed sufficiently severe, mosquitoes are controlled through aerial spraying. Similarly, rabies control should depend on elimination of the cat and dog populations when the threat is deemed sufficiently great.

Chemotherapy with modern drugs is effective in reducing fatalities from plague, epidemic typhus, and murine typhus, and the Pasteur treatment for rabies is effective in preventing the disease. Vaccines are also known for plague, epidemic typhus, and murine typhus. However, vector control is a more efficient method of controlling and preventing epidemics of vectorborne diseases.

The recommendations for actions to combat postattack vectorborne diseases, in estimated order of importance, are as follows:

1) inform the public of dangers and actions to be taken as soon as they are recognized in the postattack period;
2) keep human and rodent populations separated in the postattack period to the greatest extent practicable, especially in the western section of the country;
3) plan to control population movements if epidemics of plague or epidemic typhus occur;
4) keep records (on local as well as state and national level) of commercial inventories of pesticides;
5) include public health personnel in civil defense organizations to direct rodent and rodent ectoparasite control, using commercial inventories of pesticides;

6) plan for delousing of human population (using commercial inventories of DDT);

7) plan to control mosquitoborne encephalitis epidemics with aerial spraying if an epidemic occurs (using commercial inventories of insecticides and military aircraft);

8) plan to direct control of cat and dog populations if rabies occurs (using private stocks of arms and ammunition).

It is estimated that if these actions are taken they will reduce the cases of and deaths from vectorborne disease by 90 percent.

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Appendix A

Appendix A

Description of the Selected Diseases

This appendix contains short descriptions, not comprehensive surveys, of the diseases selected for analysis. The descriptions are intended as a brief overview for readers not familiar with vectorborne diseases.

A. Plague[A-1/]

Plague, an acute infectious disease caused by the bacillus Pasteurella pestis, is maintained in many regions of the world as a continuous chain of infection through wild or commensal rodents and a flea vector. Sporadically man becomes involved through the bite of an infected flea or through direct contact with an infected rodent. Although in India plague has been associated since antiquity with a die-off of the rat population, the vital importance of the rat in plague was not generally accepted until a decade after Kitasato and Yersin discovered the causative agent in 1894.

In man the two chief clinical forms of the disease are bubonic and pneumonic; septicemia, tonsillar, and pulmonary types have also been observed. The bubonic form gets its name from the characteristic inflammation of lymph nodes (buboes). It is generally believed that an epidemic of pneumonic plague is started when a bubonic case develops secondary pneumonia and initiates the man-to-man spread of primary pneumonic plague (cases start in pneumonic form without initial bubonic form). Usually only a small percentage of bubonic cases develop secondary lung involvement. However, environmental, nutritional, and stress factors may increase the probability of conversion to the pneumonic form; Wu Lien-Teh notes that lowering resistance through catching a cold or a vitamin deficiency (particularly vitamin A) may increase the rate of conversion to pneumonic form.

A-1/ This description of plague was condensed from:

K. F. Meyer, "Plague," Chapter 24, Diseases Transmitted from Animals to Man. Springfield, Illinois: Charles C. Thomas, 1955, pp. 467-508.

Wu Lien-Teh, A Treatise on Pneumonic Plague. Geneva: League of Nations Health Organization, 1926.

R. Pollitzer, Plague. Geneva: World Health Organization, 1954.

P. E. Sartwell, Maxcy-Rosenau Preventive Medicine and Public Health, 9th ed. New York: Appleton-Century-Crofts, 1965, pp. 328-331.

L. Kartman, M. I. Goldenburg, W. T. Hubbert, "Recent Observations on the Epidemiology of Plague in the United States," American Journal of Public Health, Vol. 56, No. 9 (September 1966), pp. 1554-1569.

E. Gordon, Control of Communicable Diseases in Man, 10th ed. New York: The American Public Health Association, 1965.

Bubonic plague in man has an incubation period of 2-6 days. The pneumonic form develops in an even shorter time; death is likely to occur in 2-4 days.

Wu Lien-Teh reported that the bacillus appears to gain virulence as a pneumonic epidemic progresses. The pulmonary form runs a rapid course with many patients dying before reaching the hospital. Because of rapid death, lack of pneumonic foci, and consequent lack of infectious sputum, pulmonary cases have low infectivity, giving a potential mechanism of self-limitation for pneumonic plague epidemics.

B. Epidemic Typhus[A-2/]

Epidemic typhus fever, an acute infectious disease caused by *Rickettsia prowazeki*, is transmitted from man to man by the human body louse (*Pediculus humanus corporis*). Transmission of typhus by the louse was first demonstrated experimentally in 1909 by Nicolle, Comti, and Conseil; and *R. prowazeki* was isolated and named in 1916 by da Rocha-Lima. The rickettsiae occur in the blood of patients during the febrile (fever) period; the louse becomes infected by feeding on febrile patients. The infected louse invariably succumbs to the infection, usually after 7-10 days although it may survive up to 24 days. Unfortunately, lice tend to leave a febrile patient and abandon a corpse to seek a new host. Transmission is usually effected by rubbing infected louse feces into abrasions of the skin (e.g., the bite puncture or scratches). Although it has been demonstrated to be possible to acquire typhus through breathing dried, infected louse feces, reducing the louse population through effective delousing will terminate an epidemic.

The incubation period is usually 8-12 days; untreated case fatality rates vary from 10-40 percent. Factors which influence the fatality rate are the nutritional state and presence or absence of complicating diseases.

Man is the reservoir of infection during interepidemic periods; Brill-Zinsser disease is a recrudescent form of epidemic louseborne typhus in persons previously infected with *R. prowazeki*. Brill-Zinsser disease may occur in the absence of

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A-2/ P. H. Top, Communicable and Infectious Diseases, 5th ed. St. Louis: The C. V. Mosby Company, 1964.

K. F. Maxcy, Rosenau, Preventive Medicine and Public Health, 8th ed. New York: Appleton-Century-Crofts, Inc., 1956.

E. S. Murray, *et al.*, "Brill's Disease I:Clinical and Laboratory Diagnosis," Journal of the American Medical Association, Vol. 142 (1950), p. 1059.

E. S. Murray and J. E. Snyder, "Brill's Disease II: Etiology," American Journal of Hygiene, Vol. 53 (1951), p. 22.

pediculosis (lousiness), but these patients are infectious and may start an epidemic in the presence of pediculosis. Of 538 cases reported before 1934 in New York and Boston, 95 percent occurred in individuals of foreign birth; 90 percent of these were Jewish, 94 percent of whom were born in regions of Southeastern Europe where epidemic typhus was common. Studies by Murray and associates in 1950 reported cases of Brill's disease (all were foreign-born Jewish immigrants) which proved that patients infect the lice which feed on them.

Top makes the appropriate (for the present analysis) comment:

> "The season in which classical typhus occurs most commonly is the colder months. Epidemics reach their peak in later winter and taper off in the spring. Typhus thrives under conditions of human misery which predispose to an increase in louse infestation, such as crowding of people together, lack of fuel, inadequate facilities for bathing, and weather so cold that the same garments are worn continuously day and night for months at a time. Epidemic typhus could be expected to appear rapidly under the chaotic conditions that probably would exist among survivors of a mass nuclear attack. The influence that the accompanying radiation would exert is uncertain but it might increase susceptibility, precipitate recrudescense of latent typhus (see Brill-Zinsser disease), and hasten the occurrence of large-scale outbreaks."

This opinion is supported by the historical association of epidemic typhus with war and famine.

C. Murine Typhus[A-3/]

Murine typhus, an acute infectious disease caused by the *R. prowazeki*, var. *typhi* (*R. mooseri*), is transmitted sporadically to man from animal hosts. The hosts are the murine rodents (mainly *R. rattus* and *R. norvegicus*). The usual vector is the rat flea *Xenopsylla cheopis*. Although theoretically possible, the man-vector-man transmission of the disease is inconsequential; like epidemic typhus, there is no man-to-man transmission.

The course of the disease is similar to that of epidemic typhus except that the untreated fatality rate of about 2 percent is much lower in all ages. Although the illness lasts but 2 weeks, a patient is usually prostrated and weak at its termination; thus it may be another week before he can get out of bed and up to 2 months before he can resume work. The patient is likely to be nervous and depressed for some time.

A-3/ F. H. Top, *op. cit.*

K. F. Maxcy, *op. cit.*

G. J. Love and W. W. Smith, "Murine Typhus Investigation in Southwestern Georgia," *Public Health Reports*, Vol. 75 (May 1960), pp. 429-440.

Communicable Disease Center, *Morbidity and Mortality*, Vol. 15, No. 52 (Dec. 24, 1966), U. S. Department of Health, Education and Welfare, Public Health Service.

The disease usually occurs among men working in food storage (especially grain) because they are close to rats and likely to be bitten by rat fleas. The disease was at a maximum during the early 1940's in the Southern states, mainly Georgia and Alabama; in 1944 there were 5,213 cases reported. Rodent and ectoparasite control measures were instituted in the 1940's and reported cases dropped to 32 by 1966.

D. Arthropodborne Encephalitis[A-4/]

The three arthropodborne encephalitides considered in this analysis are the mosquitoborne diseases--eastern equine, western equine, and St. Louis encephalitis. These acute inflammatory diseases involving parts of the brain, spinal cord, and meninges (the membranes covering the brain and spinal cord) are of short duration. All three may leave permanent brain damage. Each is caused by a specific virus identified by the disease name; all are transmitted to man by the bite of an infected mosquito although both man and the equine species are accidental hosts. To facilitate comparisons of the three types, pertinent data are summarized in Table A-1.

Table A-1

COMPARISON OF MOSQUITOBORNE ENCEPHALITIDES

Encephalitides	Characteristics of Encephalitides						
	Major Vector Mosquitoes	Major Hosts	Age of Maximum Morbidity	Main Location	Size of Large Epidemics	Untreated Mortality Rate	Host-vector Relationship Proven
Eastern equine	T. perturbans	Fowl	> 10 yrs.	Rural	> 150 total > 10/group	70%	1930
Western equine	C. tarsulis A. freebosni C. pipiens pipiens	Fowl	> 1 yr.	Rural	Total 1574 in N. & S. Dakota, Nebraska & Montana (1941)	2-15%	1931
St. Louis	C. quinque-fasciatus C. nigripalpus C. pipiens pipiens C. tarsulis	Fowl	Approx. Uniform for All Ages	Urban and Sub-urban	Total 1100 in St. Louis (1932)	10-20%	1945

A-4/ This discussion of mosquitoborne encephalitis was condensed from:
Top, op. cit.
Maxcy, op. cit.
Gordon, op. cit.
Sartwell, op. cit.

E. Rabies[A-5/]

Rabies, although rare in man, is well known because of the near 100 percent fatality of persons who contract the disease. Rabies is an acute, rapidly fatal neurotropic (having its principal effect on the nervous system) viral infection communicated from an infected animal through a wound, usually produced by biting. The average incubation period in man is six weeks, but is highly variable with recorded extremes of 10 to 210 days. Although it is well known that rabies is almost 100 percent fatal to man once the disease has become acute, it is less well known that past data indicate that only 3-10 percent of persons bitten by rabid animals actually contract the disease in the absence of treatment. The fatality rate is highly dependent upon the location of the bite--the farther from the brain and the more clothes present, the less the danger.

All mammals are susceptible to rabies, and it is maintained in many areas in wildlife despite its control in dogs. Skunks, foxes, coyotes, and wolves are among the more commonly infected mammals. Although many persons receive the Pasteur treatment because exposure is only suspected (the animal having been lost), the number of people receiving the treatment in the United States is only approximately 30,000 per year.

A-5/ This discussion of rabies was condensed from:
Top, *op. cit.*
Maxcy, *op. cit.*
Sartwell, *op. cit.*

Appendix B

Appendix B

List of Wild Rodents Found Naturally Plague-Infected in the Western United States

Family and Subfamily	Species	State
Rodents:		
Geomydae (Gophers)	Thomomys bottae	California; ? Colorado
	Th. fossor	Colorado*
Heteromyidae Dipodomyinae	Kangaroo rats:	
	Dipodomys sp.	Texas
	Dipodomys ordi	Washington
	Perognathus parvus	Washington*
Muridae	Wood rats:	
	Neotoma algibula	Arizona; New Mexico
	N. cinerea occidentalis	California
	N. desertorum	Nevada; Utah
	N. fuscipes	California; Oregon*
	N.f. mohavensis	Nevada
	N. intermedia	California
	N. lepida	? Utah
	N. micropus	Texas
Gricetinae	Grasshopper mice:	
	Onychomys sp.	Texas*
	O. leucogaster	New Mexico*
	O. torridus	New Mexico*
	Peromyscus boylii	Arizona*
	P. leucopus	New Mexico; California*
	P. maniculatus	New Mexico; California* Washington*
	P. truei gilberti	California
	P. t. truei	California; New Mexico
	P. t. nevadensis	Utah
	Reithrodontomys megalotis	California;* Kansas* New Mexico*
	Sigmodon hispidus	New Mexico*
Muridae-Microtinae	Voles:	
	Lagurus crutatus	Washington*
	Microtus californicus	California
	M. montanus	Oregon; Washington*
	M. manus	Washington*
	M. townsendi	Washington
Sciuridae	Squirrels:	
	Citellus armatus	Western United States
	C. beecheyi beecheyi	California
	C.b. douglasi	California; Oregon
	C.b. fisheri	California
	C.b. nudipes	California*
	C. beldingi beldingi	California
	C.b. oregonus	California; Nevada; Oregon

Family and Subfamily	Species	State
Sciuridae (cont.)	<u>Squirrels</u>:	
	C. columbianus columbianus	Washington
	C. c. ruficaudus	Oregon
	C. idahoensis	Idaho*
	C. lateralis chrysodeirus	California
	C. lateralis	Wyoming*
	C. leucurus	Arizona;* California*
	C. mexicanus	New Mexico*
	C. richardsoni elegans	Wyoming
	C. r. nevadensis	Nevada
	C. r. richardsoni	Montana* (a)
	C. spilosoma major	New Mexico*
	C. townsendi	Idaho*
	C. tridecemlineatus	New Mexico;* Texas*
	C. variegatus grammurus	Utah; Arizona;* Colorado;* New Mexico*
	C.v. utah	Utah
	C. washingtoni loringi	Washington
	C.w. washingtoni	Washington
	<u>Prairie dogs</u>:	
	Cynomys sp.	Colorado;* Texas*
	Cynomys gunnisoni gunnisoni	New Mexico
	C. g. zuniensis	Arizona; New Mexico
	C. leucurus	Wyoming*
	C. ludovicianus	Colorado; Kansas; Montana; New Mexico; Texas; Wyoming
	C. parvidens	Utah
	<u>Flying squirrel</u>:	
	Glaucomys sabrinus lasivus	California
	<u>Marmots</u>:	
	Marmota flaviventris subsp.	Colorado; Oregon; New Mexico* (b)
	M. f. avara	Oregon*
	M. f. engelhardti	Montana; Utah; Wyoming
	M. f. nosophora	Montana
	<u>Chipmunks</u>:	
	Tamias minimus	Washington*
	T. quadrivittatus frater	California; Nevada
	Tamiasciurus douglasi	California
<u>Lagomorpha</u>:		
Leporidae	<u>Rabbits</u>:	
	Lepus californicus	California
	Sylvilagus audobonii	New Mexico
	S. bachmani	California
	S. nuttalli	Washington

* The presence of natural plague infection was detected only in the fleas infesting these rodents.

(a) A prairie dog, <u>Cynomys mexicanus</u>, was also found naturally plague-infected in New Mexico.

(b) Naturally plague-infected fleas were found on this subspecies in British Columbia, Canada.

SOURCE: "Plague in the Americas," Scientific Publication No. 115. Washington, D. C.: Pan American Health Organization, 1965.

Appendix C

Appendix C

Glossary of Selected Chemical Terms

Allethrin - a synthetic analogue of the pyrethrum group.

ANTU - a contraction of alpha-naphthylthiourea.

BHC - a contraction of benzene hexachloride.

DDT - a contraction of the generic name dichloro-diphenyl-trichloroethane.

Lindane - the gamma isomer of benzene hexachloride.

M-1960 - a flea repellent containing N-butylacetanilide; benzyl benzoate; 2-butyl, 1-2-ethyl-1, 3-propanediol with Tween 80 as an emulsifier.

MYL powder - a louse powder containing pyrethrins (with or without allethrin), a pyrethrum synergist, and an ovicide.

NBIN concentrate - a delousing emulsion containing benzyl benzoate, DDT, benzocaine, and Tween 80.

Pyrethrum - a botanical insecticide extracted from *Chrysanthemum cinerariaefolium*, formerly classified in the genus *Pyrethrum*.

Pyrophyllite - a dust prepared from hydrate of aluminum silicate used as a diluent for insecticides.

Toxaphene - a chlorinated camphene insecticide.

Appendix D

APPENDIX D

PESTICIDE PRODUCERS AND FORMULATORS

Source: Farm Chemicals 1967 Handbook, Meister Publishing Co., Willoughby, Ohio.

State	Town	Number of Companies: Basic Producer Technical Pesticides	Number of Companies: Pesticide Formulator or Distributor
Alabama	Anniston	1	
	Axis	1	
	Bessemer		2
	Birmingham		3
	Dadeville		1
	Decatur		1
	Demopolis		1
	Dothan		1
	Florence		1
	Foley		1
	Gantt		1
	Greenville		1
	Headland		1
	Madison		1
	McIntosh	1	
	Mobile		2
	Montgomery		5
	New Brockton		1
	Oxford	1	
	Peterman		1
	Pike Road		1
	Robertsdale		1
	Selma		1
	Summerdale		1
	Sylacauga		1
	Talladega		1
	Troy		1
	Tuskegee		1
	Wetumpka		1
Alaska	Anchorage		1
Arizona	Casa Grande		1
	Coolidge		1
	Glendale		2
	Parker		1
	Phoenix		10
	Tolleson		1
	Willcox		2
	Yuma		4
Arkansas	De Witt		1
	Jacksonville	1	
	Little Rock	2	1
	Magnolia		1
	North Little Rock		3
	Pine Bluff		3
	Stuttgart		2
	Texarkana		1

Arkansas (cont'd.)	Van Buren		2
	West Helena		1
California	Agnew	1	
	Altadena		1
	Anaheim		2
	Anderson		1
	Arbuckle		1
	Artesia		1
	Arvin		1
	Azusa		1
	Bakersfield		4
	Banta		1
	Belmont		1
	Berkeley		1
	Blythe		4
	Boron	1	
	Brawley		2
	Brisbane		1
	Buena Park	1	
	Burbank		3
	Burlingame	1	1
	Calipatria		2
	Chula Vista		2
	City of Industry		1
	Coachella		1
	Corona	1	3
	Courtland		1
	Covina		1
	Cypress		1
	Dairy Valley		1
	Davis		1
	Delano		2
	Dinuba		1
	Dixon		2
	Edison		1
	El Centro		3
	El Segundo		1
	Five Points		1
	Fremont	1	1
	Fresno		8
	Gardena	1	
	Hamilton City		1
	Hanford		1
	Hollister		1
	Imperial		1
	Lancaster		1
	Lathrop		1
	Linden		1
	Lodi		1
	Long Beach		2
	Los Angeles	5	22
	Martinez		1
	Maxwell		1
	Mendota		1
	Modesto		1
	Morgan Hill		1

California (cont'd.)	Napa		2
	North Hollywood		2
	Oakland		2
	Oildale		2
	Ojai		1
	Orange		1
	Oxnard		6
	Palo Alto		1
	Pasadena		1
	Paso Robles		1
	Pittsburg		1
	Port Chicago		1
	Redondo Beach		1
	Rialto		1
	Richmond	1	2
	Riverside		1
	Robbins		1
	Sacramento		3
	Salinas		3
	San Diego		1
	San Francisco	2	10
	San Jacinto		1
	San Jose	1	3
	Santa Ana		3
	Santa Cruz		1
	Santa Fe Springs		2
	Santa Maria		2
	Santa Rosa		2
	Sebastopol		1
	Shafter		3
	South Gate		1
	Stockton		2
	Stratford		1
	Thermal		1
	Torrance		1
	Traver		1
	Tulare		2
	Tulelake		1
	Turlock		1
	Tustin		1
	Union City		2
	Van Nuys		2
	Visalia		1
	Vista		2
	Walnut Grove		1
	Wasco	1	1
	Watsonville		2
	Westley		1
	Whittier		3
	Wilmington	1	
	Woodland		4
	Yuba City		2
Colorado	Arvada		1
	Blanca		1
	Brush		1

Colorado (cont'd.)	Colorado Springs		1
	Commerce City		1
	Denver	2	9
	Durango		1
	Eaton		1
	Englewood		1
	Ft. Collins		2
	Ft. Lupton		1
	Grand Junction		1
	Greeley		4
	Henderson		1
	Julesburg		1
	LaSalle		1
	Longmont		1
	Loveland		1
	Lucerne		1
	Manzanola		1
	Monte Vista		1
	Olathe		1
	Ordway		1
	Pueblo		1
	Severance		1
	Sterling		1
	Wiggins		1
	Windsor		1
	Wray		1
Connecticut	Cromwell		1
	Manchester		1
	Naugatuck	1	1
	New Haven		1
	Orange		1
	Portland		1
	Simsbury		1
	Stamford		2
	Waterbury		2
	West Haven		1
	Woodbury		1
Delaware	Bridgeville		1
	Wilmington	2	1
Florida	Alachua		1
	Arcadia		1
	Belle Glade		6
	Boynton Beach		1
	Bradenton		2
	Clermont		1
	Crescent City		1
	Dade City		3
	Daytona Beach		1
	De Funiak Springs		1
	Fort Lauderdale		2
	Fort Myers		2
	Fort Pierce		2
	Frostproof		1
	Gainesville		1
	Haines City		2
	Hialeah		2
	Hollywood		1
	Homestead		3
	Jacksonville		5
	Lake Alfred		1

Florida (cont'd.)	Lake Worth		2
	Lakeland		1
	Leesburg		1
	Live Oak		1
	Marianna		2
	Miami		4
	Mount Dora		1
	Mulberry		1
	Ocala		1
	Orange City		1
	Orlando	1	7
	Oviedo		1
	Pahokee		1
	Palmetto		1
	Plant City		3
	Plymouth		1
	Pompano		1
	Pompano Beach		1
	Port St. Joe	1	
	Princeton		3
	St. Augustine		1
	St. Petersburg		2
	Sanford		2
	Stuart		1
	Tampa		6
	Weirsdale		1
	West Palm Beach		1
	Winter Garden		3
	Winter Haven		2
	Winter Park		1
Georgia	Albany		4
	Americus		3
	Atlanta	2	20
	Augusta		2
	Bainbridge		1
	Brunswick	1	
	Cairo		1
	Camilla		2
	Carrollton		1
	Cedartown		1
	Chamblee		1
	College Park		2
	Colquitt		1
	Columbus		1
	Conyers		2
	Cordele		2
	Dawson		1
	Decatur		1
	Doerun		1
	Douglas		2
	East Point		2
	Edison		1
	Fort Valley		1
	Hahira		1
	Macon		3
	Madison		1

Georgia (cont'd.)	Manchester		1
	McDonough		1
	Monroe		1
	Monticello		1
	Moultrie		2
	Nashville		1
	Newnan		1
	Ocilla		1
	Oglethorpe		1
	Pelham		1
	Perry		1
	Powder Springs	1	1
	Quitman		1
	Register		1
	Savannah		2
	Soperton		1
	Statesboro		1
	Sylvester		1
	Thomasville		1
	Tifton		3
	Tucker		2
	Valdosta		2
	Vidalia		1
	Waynesboro		2
Hawaii	Hilo, Hawaii		1
	Honolulu, Oahu		6
	Kahului, Maui		1
	Puhi, Kauai		1
Idaho	Bancroft		1
	Boise		2
	Caldwell		1
	Idaho Falls		1
	Lewiston		1
	Nampa		1
	Rupert		1
	Twin Falls		1
Illinois	Alton		1
	Astoria		1
	Avon		1
	Bement		1
	Benton		1
	Brocton		1
	Calumet City		1
	Cambridge		1
	Carrollton		1
	Centralia		1
	Cerro Gordo		1
	Champaign		1
	Chicago	3	22
	Chicago Heights		2
	Cisne		1
	Clinton		1
	De Kalb		2

Illinois (cont'd.)	Dwight		1
	East St. Louis		1
	Effingham		3
	Elizabeth		1
	Elk Grove Village		1
	El Paso		2
	Erie		1
	Eureka		1
	Evanston		1
	Fairbury		1
	Fairfield		1
	Franklin Park		1
	Freeport		2
	Granville		1
	Grayville		1
	Greenfield		1
	Harvel		1
	Havana		1
	Hillside		1
	Hudson		1
	Hutsonville		1
	Jacksonville		1
	Joliet		1
	Kilbourne		1
	Kinmundy		1
	Latham		1
	Lincoln		1
	Lodge		1
	Louisville		1
	Lyndon		1
	Marine		1
	Marion		1
	Marshall	1	
	Mattoon		1
	Maywood		1
	Mazon		1
	McLeansboro		1
	Mendon		1
	Meredosia		1
	Metcalf		1
	Milledgeville		1
	Minier		1
	Minooka		1
	Monmouth		2
	Monroe Center		1
	Monsanto	1	
	Monticello		2
	Morris		2
	Morrison		1
	Morton Grove		1
	Mt. Sterling		1
	Mt. Vernon		1
	National Stock Yards		1
	New Holland		1
	Newark		1
	Odell		1
	Oneida		1
	Paris		1

Illinois (cont'd.)	Peoria		1
	Peotone		1
	Pontiac		1
	Pulaski		1
	Quincy		1
	Ramsey		1
	Ringwood	1	1
	Rochester		1
	Rockford		3
	Rushville		1
	Salem		1
	Savoy		1
	Skokie		2
	Speer		1
	Stronghurst		1
	Sullivan		1
	Taylorville		1
	Tremont		1
	Union		1
	Viola		1
	Wataga		1
	Waterloo		1
	Waukegan		1
	Wellington		1
	Wheaton		1
	White Hall		1
	Windsor		1
	Woodstock	1	
	Wyoming		1
Indiana	Arcadia		1
	Bentonville		1
	Bluffton		1
	Boone Grove		1
	Boonville		1
	Boswell		1
	Bremen		1
	Bridgeton		1
	Brook		2
	Brookville		1
	Chandler		1
	Clay City		1
	Colfax		1
	Columbus		1
	Connersville		1
	Crown Point		1
	Dundee		1
	Dunkirk		1
	Durbin		1
	East Chicago	1	
	Evansville		3
	Forest		1
	Fort Branch		1
	Fowler		1
	Frankfort		1
	Gary		1

Indiana (cont'd.)	Hanna		1
	Holton		1
	Huntington		1
	Indianapolis	1	9
	Lakeville		1
	Lowell		1
	Lyons		1
	Malden		1
	Middletown		1
	Monon		1
	Monticello		2
	Nappanee		1
	New Albany		1
	New Castle		1
	New Haven		1
	North Grove		1
	Otterbein		1
	Patoka		1
	Plymouth		2
	Princeton		1
	Rochester		1
	Romney		1
	Russellville		1
	Shipshewana		1
	Stillwell		1
	Switz City		1
	Sycamore		1
	Terre Haute	1	
	Tipton		1
	Valparaiso		2
	Vincennes		2
	Walton		1
	West Lafayette	1	
	Wheeler		1
	Wingate		1
Iowa	Archer		1
	Battle Creek		1
	Blairstown		1
	Brandon		1
	Breda		1
	Burlington		1
	Cedar Rapids		1
	Charles City		1
	Clarence		1
	Corning		1
	Council Bluffs		1
	Crawfordsville		1
	Creston		1
	Delmar		1
	Denison		1
	Des Moines		7
	Dike		1
	Dubuque		1
	Eldora		1

Iowa (cont'd.)	Emmetsburg	1
	Fairfield	2
	Fort Dodge	1
	Hamburg	1
	Hubbard	1
	Hudson	1
	Humeston	1
	Indianola	1
	Kanawha	1
	Kensett	1
	Keswick	1
	Lenox	1
	Lohrville	1
	Marcus	1
	Mason City	2
	Matlock	1
	Maynard	1
	Monmouth	1
	Monticello	1
	Moravia	1
	Muscatine	1
	Nevada	1
	New Hampton	1
	New Sharon	1
	Oelwein	2
	Ottumwa	1
	Perry	1
	Pocahontas	1
	Quimby	1
	Readlyn	1
	Rippey	1
	Sac City	2
	Saint Ansgar	1
	Sergeant Bluff	1
	Sibley	1
	Terril	1
	Tipton	1
	Toledo	1
	Traer	1
	Trenton	1
	Tripoli	1
	Wallingford	1
	Waukon	1
	West Branch	1
	Whiting	2
	Williamsburg	1
	Winfield	1
	Yale	1
Kansas	Abilene	1
	Attica	1
	Bird City	1
	Buck Creek	1
	Dighton	1
	Ft. Scott	1

Kansas (cont'd.)	Garden City		1
	Goodland		1
	Haven		1
	Herington		1
	Hiawatha		2
	Highland		1
	Iola		1
	Kansas City	1	4
	Larned		1
	Lawrence		1
	Neodesha		1
	Park		1
	Parsons		1
	Plains		1
	Salina		1
	Waterville		2
	Wichita	1	2
	Zenith		1
Kentucky	Campbellsville		1
	Elkton		1
	Franklin		1
	Glasgow		1
	Lebanon		1
	Lexington		2
	Liberty		1
	Louisville		3
	Mayfield		1
	Maysville		1
	Morganfield		1
	Russellville		1
	Shelbyville		1
	Somerset		1
	South Union		1
Louisiana	Abbeville		1
	Alexandria		1
	Baton Rouge	1	2
	Bossier City		1
	Bunkie		1
	Deridder	1	
	Gilliam		2
	Gretna		1
	Lafayette		1
	Lake Charles	1	
	Loreauville		1
	Mansfield		2
	Metairie		1
	Monroe		3
	Natchitoches		1
	New Orleans		17
	Opelousas		1
	St. James		1
	Schriever		1
	Shreveport		2

Louisiana (cont'd.)	West Monroe		1
	Winnsboro		1
Maine	Caribou		1
	Ft. Kent		1
	Houlton		1
	Presque Isle		3
Maryland	Baltimore	4	14
	Bethesda		1
	Chestertown		1
	Elkton		1
	Frederick		1
	Hagerstown		2
	Hancock		1
	Pocomoke		1
	Salisbury		2
	Snow Hill		2
	Whiteford	1	
Massachusetts	Arlington		1
	Ayer		1
	Boston		1
	Cambridge		1
	Canton		1
	Chelsea		1
	Holbrook		1
	Lowell		1
	Malden		1
	Taunton		1
	Tewksbury		1
	Woburn		1
Michigan	Akron		2
	Bay City		1
	Benton Harbor		1
	Britton		1
	Calumet	1	
	Detroit		1
	Eau Claire		1
	Edmore		1
	Fennville		1
	Fremont		1
	Grand Ledge		1
	Grand Rapids		2
	Greenville		1
	Kalamazoo	1	2
	Lake Linden	1	
	Lake Odessa		1
	Lansing		3
	Midland	1	2
	Muskegon		1
	Niles		1
	Riga		1
	St. Johns		1

Michigan (cont'd.)	Saint Louis	1	
	South Haven		1
	Woodbury		1
	Wyandotte		1
Minnesota	Albert Lea		1
	Appleton		1
	Barnesville		1
	Blooming Prairie		1
	Cambridge		1
	Castle Rock		1
	Cosmos		1
	Dawson		1
	Delft		1
	Dilworth		1
	Duluth		1
	East Grand Forks		1
	Eden Prairie		1
	Elmore		1
	Fairfax		1
	Glyndon		1
	Heron Lake		1
	Hutchinson		1
	Jackson		1
	Lake Crystal		1
	Lake Elmo		1
	Litchfield		1
	Mankato		2
	Marshall		1
	Minneapolis		14
	Morgan		1
	Morris		1
	New Ulm		1
	Owatonna		1
	Redwood Falls		1
	Rochester		1
	St. Louis Park		1
	St. Paul		8
	Sauk Centre		2
	Sherburn		1
	Stephen		1
	Welcome		1
	Willmar		2
	Windom		1
	Winona		2
Mississippi	Aberdeen	2	1
	Amory	1	1
	Benoit		1
	Canton		1
	Clarksdale		2
	Cleveland		2
	Greenville		3
	Greenwood		2
	Grenada		1

Mississippi (cont'd.)	Hattiesburg	1	2
	Houston		1
	Indianola	1	
	Jackson		2
	Leland		1
	Lula		1
	Magee		1
	Marks		2
	Meridian		1
	Pontotoc		1
	Tupelo		2
	Yazoo City		1
Missouri	Auxvasse		1
	Bowling Green		1
	Braymer		1
	Buell		1
	Camdenton		1
	Carrollton		1
	Fredericktown		1
	Gallatin		1
	Hale		1
	Hazelwood		1
	Holden		1
	Hollister		1
	Kansas City	2	12
	Laclede		1
	Laredo		1
	Liberal		1
	Liberty	1	1
	Maryland Heights		1
	Monett		1
	Montgomery City		1
	Norborne		1
	North Kansas City		1
	Palmyra		1
	Paris		1
	Plattsburg		1
	Portageville		1
	St. Joseph	2	3
	St. Louis	5	18
	Salisbury		2
	Springfield		1
	Weatherby		1
	West Boro		1
	West Plains		1
	Weston		1
	Windsor		1
Montana	Butte	1	
	Miles City		1
Nebraska	Bayard		2
	Beatrice		1
	Blair		1

Nebraska (cont'd.)	Byron		1
	Central City		1
	Fairbury		1
	Fairmont		1
	Falls City		1
	Fremont		1
	Genoa		1
	Grand Island		2
	Lyman		1
	Lyons		1
	McCook		1
	Milford		1
	Minatare		1
	Morrill		1
	Nebraska City		1
	Norfolk		2
	Oakland		1
	Omaha		10
	Ponca		1
	Shickley		1
	South Omaha		1
	South Sioux City		1
	Tekamah		1
Nevada	Fallon		1
	Henderson	1	
	Las Vegas		1
	Lovelock		1
	Reno		2
New Jersey	Bloomfield		1
	Bound Brook		2
	Bridgeton		2
	Burlington	1	
	Camden		1
	Carlstadt		1
	Clark	2	
	Clifton		1
	Collingswood		1
	Cranford		1
	Dayton		2
	East Brunswick		1
	East Orange		1
	East Rutherford		1
	Edgewater		1
	Edison		1
	Fair Lawn	1	1
	Fords	1	1
	Garfield		1
	Haddonfield		1
	Hammonton		2
	Hawthorne	1	1
	Ho-Ho-Kus	1	1
	Jersey City		3
	Kearney	1	

New Jersey (cont'd.)	Kenilworth		1
	Linden	3	
	Malaga		1
	Metuchen		1
	Moonachie		1
	Moorestown		2
	Mount Holly		1
	Murray Hill		1
	New Brunswick	1	1
	Newark	3	1
	Northvale		1
	Passaic	1	
	Paterson		1
	Pine Brook		1
	Piscataway		1
	Pittstown		1
	Princeton	2	1
	Rahway		1
	Riverton		1
	Robbinsville	1	3
	Saddle Brook		1
	South Kearney		1
	South Plainfield		2
	Springfield		2
	Trenton		2
	Union	1	1
	Vineland	2	3
	West Caldwell		1
	Wood-Ridge	1	1
New Mexico	Albuquerque		4
	Anthony		1
	Las Vegas		1
	Lovington		2
	Mesquite		1
	Portales		1
	Roswell		1
	Springer		1
New York	Alton		1
	Ardsley	1	
	Auburn		1
	Barker		1
	Batavia		1
	Blue Point, L. I.		1
	Brooklyn		6
	Buffalo		5
	Cambridge		1
	Canastota		1
	Clinton Corners	1	1
	East Farmingdale, L. I.		1
	Farmingdale, L. I.		2
	Flushing		1
	Geneva		1
	Hall		1

New York (cont'd.)	Hermon		1
	Hicksville, L. I.		1
	hollis		1
	Ithaca		1
	Jamaica		1
	Laurel Hill, L. I.	1	
	LeRoy		1
	Lindenhurst, L. I.		1
	Long Island City		2
	Lyons		1
	Malverne		1
	Marion		1
	Medina		2
	Middleport	2	1
	Middletown		1
	Mt. Vernon		1
	Natural Bridge		1
	New Rochelle		1
	New York	19	20
	Niagara Falls	1	
	Ogdensburg		1
	Ossining	1	1
	Patchogue		1
	Philmont		1
	Pleasant Valley		1
	Port Chester		1
	Rochester		1
	Savannah		1
	Sodus		1
	Spring Valley		1
	Syracuse		1
	Utica		1
	White Plains	1	1
North Carolina	Aberdeen		2
	Ahoskie		1
	Apex		1
	Ayden		1
	Boone		1
	Canton		1
	Cary		2
	Clayton		1
	Dunn		1
	Elizabeth		1
	Farmville		1
	Fayetteville		1
	Gastonia		1
	Goldsboro	1	3
	Greensboro		1
	Greenville	1	1
	Hendersonville		1
	Kinston		2
	Lumberton		1

North Carolina (cont'd.)	Newland		1
	Princeton		1
	Raleigh	1	3
	Roanoke Rapids		1
	Roxboro		1
	Sanford		1
	Statesville		2
	Teachy		1
	Wallace		1
	Warrenton		1
	Washington		2
	Williamston		1
	Wilmington		3
	Wilson	1	
	Winston Salem		1
North Dakota	Amenia		1
	Fargo		2
	Grafton		3
	Grand Forks		2
	Jamestown		1
	Park River		1
	St. Thomas		1
	Wahpeton		1
	West Fargo		1
Ohio	Alliance		1
	Andover		1
	Archbold		1
	Ashland		1
	Barberton	1	1
	Bedford		1
	Bowling Green		1
	Caldwell		1
	Chillicothe		1
	Cincinnati		1
	Cleveland	1	7
	Columbus	1	3
	Cook Station		1
	Delta		1
	Elyria		1
	Findlay		1
	Fostoria		1
	Gerald		1
	Gratis		1
	Greenville		2
	Highland		1
	Hoytville		1
	Lebanon		1
	Lima		2
	Lindsey		1
	Lytle		1
	Marietta		1
	Marion		2
	Marysville		2

Ohio (cont'd.)	Medina		1
	Melvin		2
	Napoleon		3
	Painesville		1
	Peoria		1
	Perry	1	
	Pettisville		1
	Portsmouth		1
	Richwood		1
	Roxanna		1
	Springfield		1
	Toledo		2
	VanWert		1
	Xenia		1
Oklahoma	Altus		1
	Apache		1
	Cordell		1
	Enid		1
	Frederick		1
	Kingfisher		1
	Oklahoma City		3
	Tulsa		3
Oregon	Athena		1
	Eugene		1
	Imbler		1
	Jefferson		1
	Junction City		1
	Klamath Falls		1
	Medford		1
	Milton-Freewater		1
	Milwaukee		1
	North Portland		2
	Portland		12
	Salem		4
	Stayton		1
	Tigard		1
	West Stayton		1
	Woodburn		1
Pennsylvania	Allentown		2
	Ambler	1	1
	Biglerville		1
	Butler		1
	Chester		1
	Conshohocken		1
	Ephrata		1
	Erie		1
	Everett		1
	Flemington		1
	Gardenville		1
	Gettysburg		1
	Hanover	1	1
	Huntingdon Valley		1

Pennsylvania (cont'd.)	Lancaster		2
	Lebanon	1	1
	Marcus Hook	1	
	Martinsburg		1
	Mill Hall		1
	Milton		1
	Myerstown		1
	Oxford		1
	Philadelphia	4	7
	Pittsburgh	1	3
	Pittston		1
	Pottsville		1
	Reading		2
	Shiresmantown		1
	Somerset		1
	State College		1
	Towanda		1
	West Conshohocken		1
	Wilkes-Barre		1
Rhode Island	Pawtucket		1
South Carolina	Anderson		1
	Angelus		1
	Blackville		1
	Charleston		2
	Clinton		1
	Columbia		1
	Dillon		2
	Ehrhardt		1
	Estill		1
	Fairfax		2
	Garnett		1
	Gramling		1
	Greenville		2
	Greer		1
	Hartsville		1
	Inman		1
	Jericho		1
	Kingstree		1
	Mauldin		1
	Orangeburg	1	
	Pendleton		1
	St. George		1
	Salley		1
	Spartanburg		2
	Sumter		2
	West Columbia		1
	Westminster		1
South Dakota	Aberdeen		1
	Brookings		1
	Madison		1
	Rapid City		1

Tennessee	Arlington		1
	Athens		1
	Chattanooga	2	7
	Clarksville		1
	Cleveland		1
	Copperhill	1	
	Donelson		1
	Erwin		1
	Greenville		1
	Jackson		1
	Johnson City		1
	Knoxville		6
	Lebanon		1
	Martin	1	
	Memphis	3	31
	Mt. Pleasant	1	
	Nashville	1	17
	Newport		1
	Pulaski		1
	Rutherford		1
	Springfield		1
	Winchester		1
Texas	Amarillo		2
	Anthony		1
	Austin		2
	Batesville		1
	Bishop	1	
	Bonham		2
	Brownfield		1
	Bryan		1
	Clint		1
	College Station		1
	Dallas		10
	Denver City	1	
	Dimmitt		1
	Edinburg		1
	El Campo		1
	El Paso	1	1
	Ennis		1
	Fort Worth		3
	Freeport	1	1
	Galena Park		1
	Greens Bayou	1	1
	Greenville		1
	Harlingen		2
	Hereford		1
	Houston	5	8
	Lamesa		1
	Liberty	1	1
	Llano		1
	Los Fresnos		1
	Lubbock		3
	Mathis		1
	McAllen		1

Texas (cont'd.)	Midland		1
	Mission		1
	Munday		1
	Needville		1
	Odessa		1
	Palacios		1
	Palestine		1
	Pampa	1	1
	Pasadena		1
	Pecos		1
	Plainview		1
	Port Naches	1	
	San Antonio		4
	Sulphur Springs		1
	Texarkana		1
	Tyler		1
	Uvalde		2
	Waco		2
	Weslaco		1
	West		1
Utah	Gunnison		1
	Salt Lake City		4
Vermont	Burlington		1
Virginia	Alexandria		1
	Chesapeake		1
	Chilihowie		2
	Danville		1
	Norfolk		3
	Richmond		3
	Roanoke		2
	South Norfolk		1
	West Norfolk	1	1
	Winchester		1
Washington	Almira		1
	Auburn		1
	Basin City		1
	Burlington		2
	Chewelah		1
	Colfax		1
	Connell		1
	Ellensburg		1
	Eltopia		1
	Endicott		1
	Garfield		1
	Gate	1	
	Grandview		1
	Greenacres		1
	Huntsville		1
	Kennewick		2
	LaCrosse		1
	Lind		1

Washington (cont'd.)	Lynden		2
	Monroe		2
	Moses Lake		5
	Mount Vernon		2
	Oaksdale		1
	Othello		5
	Palouse		1
	Pasco		2
	Pullman		1
	Puyallup		1
	Quincy		2
	Rockford		1
	Royal Star Route (Othello)		1
	Seattle	1	6
	Selah		1
	Spokane		8
	Sumas		1
	Sumner		1
	Sunnyside		3
	Tacoma	1	3
	Thornton		1
	Toppenish		1
	Uniontown		1
	Walla Walla		2
	Wapato		1
	Warden		1
	Wenatchee		8
	Yakima		8
	Zillah		1
West Virginia	Charles Town		1
	Charleston	2	1
	Huntington		1
	Institute	1	1
	Natrium	1	
	Nitro	3	2
Wisconsin	Bryant		1
	Burlington		1
	Butler		1
	Chippewa Falls		1
	Columbus		1
	Darien		1
	Durand		1
	Eau Claire		1
	Edmund		1
	Eldorado		1
	Elkhorn		1
	Green Bay		1
	Hillsboro		1
	Hubbleton		1
	Janesville		1
	Kenosha		1
	Madison		7
	Marinette	1	

Wisconsin (cont'd.)	Milwaukee	5
	Neillsville	1
	Oconomowoc	1
	Racine	1
	Randolpf	1
	Richland Center	1
	Stevens Point	1
	Sun Prairie	1
	Watertown	1
	Waukesha	2
Wyoming	Torrington	1
	Wheatland	1
	Worland	1

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Johnson, T. and Johnston, D. R.

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13. ABSTRACT

This study develops quantitative estimates of the potential postattack threat from vectorborne diseases. The diseases chosen for analysis on the basis of previous estimates of importance are plague, epidemic typhus, murine typhus, mosquitoborne encephalitis, and rabies. The analysis is based on a set of explicit assumptions about postattack medical services and command-and-control in the absence of specific plans to combat vectorborne diseases. The regional distribution of risk is considered. It is concluded that in the absence of specific preattack preparations, the best estimate is that 2 percent of the survivors may contract one of these diseases and 0.75 percent of the survivors may die from one of these diseases. Plague in the western states might be expected to account for one-half of the cases and two-thirds of the deaths from vectorborne diseases. Thus vectorborne diseases are a potential postattack problem, but are less of a potential hazard than the enteric or the man-to-man disease groups.

Methods of control of rodents, rodent ectoparasites, lice, and mosquitoes are reviewed. Normal inventories of pesticides are estimated to be adequate in quantity and distribution to support postattack vector control operations. Dissemination of information in the postattack period is judged to be of prime importance in controlling the vectorborne disease threat. The relative magnitude of the postattack vectorborne disease threat indicates that only low cost preattack preparations such as recognition of the threat in plans and the maintenance of records of commercial inventories are needed and are feasible.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Civil Defense						
Diseases						
Vectors						
Postattack						
Risks						
Control						

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